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BASIC PRINCIPLES OF GLASS ANNEALING

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I. Introduction

In keeping with its title, this discussion of glass annealing is substantially limited to the physical principles involved, and will not touch directly upon the practical problems of lehring. In dealing with an applied problem such as, for instance, the designing of a machine, two quite different kinds of "know how" are of almost equal importance in attaining a truly satisfactory result.

For one thing, one must have a complete understanding of what the machine will be required to do, a good mechanical insight as to what combinations of machine elements can be expected to bring about the desired result and, further, experience in the matter of which particular elements it is possible to make and assemble so that each will have proper clearance and the like. But, if such were the sum-total of the designer's capabilities, he would build a machine which, though it might be quite effective in its purpose, would probably fall very short of the ideal mechanism.

That additional factor purposely omitted from the above consists of a knowledge of the basic principles of mechanical design, including among others such things as the properties and strength of materials as well as the effect of sustained loads, accelerations, etc. upon wear and tear.

There is no difficulty in recognizing that the dividing line between these two categories of knowledge is defined by the fact that the one is specific in dealing with the problem at hand, while the other is general in its usefulness to all related problems.

So it is with the problem of annealing glassware. One could build a lehr or kiln with nothing to guide him but his desire to make a product that would hold together. By working hard enough and long enough, he would eventually hit upon a workable design and a suitable operation, but it would be fortuitous indeed if the lehr or kiln had the optimum design or if the ware were consistently brought to the most desirable stress level in the most efficient way. For a nearer approach to these latter conditions, one needs some conception of what happens inside the glass during the annealing operation, and in what way their magnitudes and the rate at which the phenomena occur depend upon the temperature and cooling rate. These are the "basic principles" to which this paper refers.

Purpose of Annealing. Let us briefly review the question of why it is desirable to anneal glass. In the forming operation, be it pressing or blowing or drawing, large temperature gradients are present. Sometimes these are more or less equally distributed (as along the length of drawn sheet), but frequently they are extremely spotty as in the case of pressed or blown ware. One important purpose of the annealing treatment accordingly is to reduce these stresses to some acceptable level so that subsequent cooling or handling or even abuses in service, such as scratching, will not cause the article to break. Since, as is well known, the reduction of forming stresses must ordinarily be accomplished at temperatures where subsequent cooling can introduce other new permanent stresses, another avowed purpose of the annealing schedule is to control the final room-temperature stresses, from that cause, to a desirable level.

Annealing very frequently increases the strength and serviceability of the article. This results from its effect in relieving the spotty stress distributions in the ware which, if permitted to remain, would add to, or subtract from, the mechanical or thermal forces incident to normal service.

There are two other possible purposes for annealing, both of a rather specialized nature, that will be mentioned in passing but otherwise not treated in detail. These have to do, first, with stabilization of properties and, second, with homogenization. It is known that ex-

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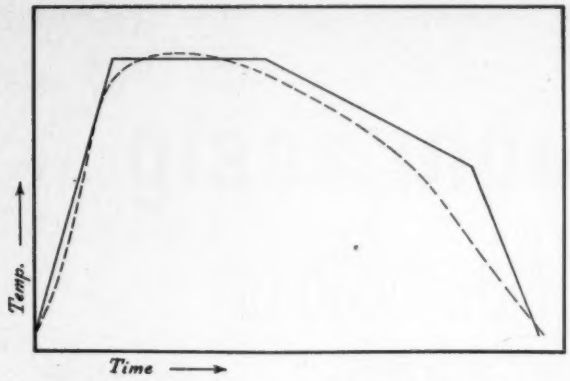

Fig. 1. Comparison between a theoretical annealing schedule and a practical schedule that might lead to an equally satisfactory result.

tended heat treatment in the lower reaches of the annealing range renders the glass less likely to change in its physical properties during subsequent service at somewhat elevated temperatures[1]. The homogenizing effects of annealing[2] can be employed to advantage only in cases where the glass already possesses extreme chemical homogeneity. Its discovery is by no means new, but the details of such treatment have been worked out in recent years so that now we have a better understanding of it and, of course, can apply it more favorably in precision optics.

According to strict usage, neither the stabilizing nor the homogenizing heat treatments can be referred to as annealing, since their purposes lie outside the scope of stress control.

The Annealing Problem. Before proceeding with a consideration of the basic principles involved in glass annealing, it will be helpful if we define the problem by breaking it down into its three major components.

Whether the glass is transferred to a lehr directly from the forming operation or is reheated from a cold condition in a lehr or kiln, the first problem has to do with the soaking out of previously introduced stresses to reduce them to a suitable level. During the soaking operation it is obvious that temperature uniformity over the whole piece is an essential condition; otherwise, we not only may fail to relieve the stresses sufficiently at one point and deform the piece at some other point, but also may introduce sufficient temperature gradient to give rise to subsequent permanent stresses of unwanted magnitude. Accordingly, one problem in the soaking operation is to provide a period in which the ware experiences a good uniform temperature throughout. The other, and in many respects simpler, problem is to prescribe the proper soaking temperature and time for most efficient annealing. This latter will of course depend mainly on the stress tolerance for the particular ware, but will also be qualified by the glass properties and thickness.

The second part of the problem has to do with the initial cooling through the critical temperature range in which thermal gradients can cause viscous flow. During this stage of the process, it is essential that all parts of the ware be subjected not only to equal cooling rates but also to a substantially uniform temperature at any given time. Let us consider briefly the effect of introducing very large ware in a relatively short lehr that is known to properly anneal articles one-quarter as large. The temperature difference between the leading edge and the trailing edge of the large ware will be roughly four times that for the smaller ware. The final stress from this cause alone will be proportionately greater and cannot be corrected by slowing down the belt. If the resulting stresses cannot be tolerated, increasing the length of the lehr is the surest solution.

In addition to the criterion just considered, we have the problem, usually simple in comparison, of specifying what the rate of cooling shall be and over what temperature range this initial part of the cooling shall extend. The answers depend upon the ware in question and upon the glass properties, as well as the stress tolerance imposed upon the final product.

On reaching a temperature at which the viscous flow of the glass is substantially unresponsive to thermal gradients, the rate of cooling is limited only to that which will not cause damage to the ware. In this stage, the problem is only to determine the safe rate and this, as before, depends on glass properties and dimensions.

We have, then, a problem of soaking temperature and time, and of two cooling rates. The solving of this problem in a theoretical way is faced with serious limitations.

II. Limitations of "Basic Principles"

There have already been indicated certain criteria that apply to the general kiln conditions if good results are to be had. It should be added that a discussion of basic annealing principles cannot take account of any departures from those criteria. Basic theory can only say what can be expected if conditions are substantially as assumed.

It becomes apparent, then, that if we assume ideal conditions under which all parts of the ware go through the same cycle simultaneously, the only temperature gradients are those due to glass thickness. Any annealing theory therefore refers to glass thickness and must be inadequate to the same extent to which real lehring practice departs from the ideal. Even at worst, of course, the theoretical result may serve to indicate in what respect a lehr is failing to do its best.

But there is a further limitation. It is impossible to take into account thickness variations—either those within a single piece of ware or those existing from piece to piece. If either of these variations is large, one can only consider the thickest expected section in calculating. And this must be the thickness between two cooling surfaces, so that in hollow ware it may be double the wall thickness.

There is one other point to be made in this connection. Figure 1 shows by the solid line the simple type of annealing schedule that can most readily be calculated. In such a schedule, it is assumed that the glass reaches the soaking temperature without alteration in its stresses. It will then soak at a definite temperature for a specified time; cooling will be linear and in two discrete sections. In reality, these conditions cannot be met and some near approach to them as shown by the dashed curve might lead to an almost exactly similar result. The calculated curve, even though it cannot be duplicated in practice, will tell us what conditions we must design the equipment for and will guarantee an approximate result. The approximation will prove in every way acceptable, provided the criteria discussed above are closely approached and a

reasonable factor of safety is applied on the stress tolerances in order to compensate for uncertainties that the theory cannot possibly take into account.

III. Stress Distribution

Let us briefly review the several kinds of stress distribution that can, and frequently do, exist across the thickness section of glass, and how these enter into the final distribution after cooling.

It has been said that the stress in glass at room temperature is equal and opposite to that which has been relieved by viscous flow during cooling. While this is often true, it is not strictly so, being based on the assumption that all stresses previously present have been reduced to zero before cooling starts, so that the only temporary stresses in cooling are those actually caused by the cooling rate. There is more than a remote chance that the cooling rate will substantially compensate for stresses already present and in such a case there will be almost no stress present at that rate. Thus there will be no release of stress but the final result will not be stress-free. In reality,[3] as will be seen presently, the final stress will be the sum of two stress distributions: the negative of that part of the cooling stress that has been released during cooling, plus the positive of the unreleased portion of the stress present before cooling.

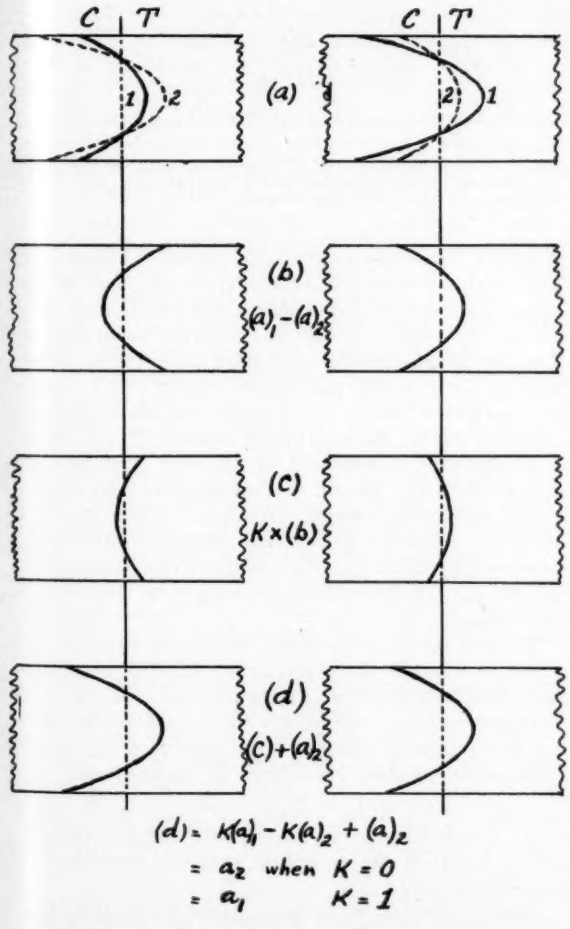

Fig. 2. Stress distributions during annealing. Initial stress "normal" type. Cooling from both surfaces. T = Tension; C = Compression.

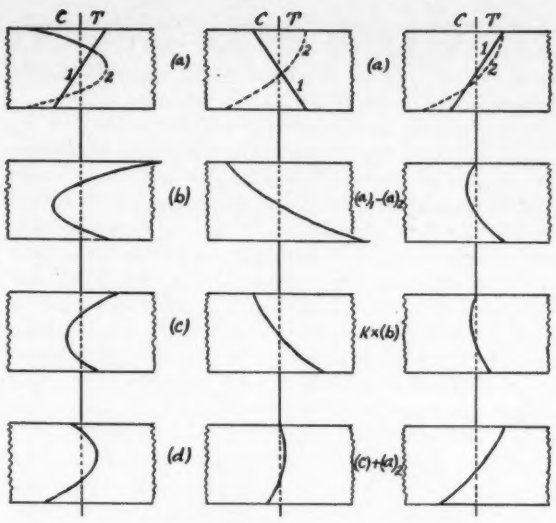

Fig. 3. Stress distributions during annealing. Initial stress "bending" type. Cooling from both surfaces, from tension surface and from compression surface.

Figure 2 demonstrates this principle for the special case of what we will call normal stress distributions, i.e., stresses of the sort that are found in a simple slab after more or less rapid cooling or rough annealing. Let us assume that (a) in both columns shows by a solid line a stress distribution #1 to which the stress already present has been reduced by soaking. The dashed line #2 represents the distribution equivalent to the cooling rate to be imposed. In the left hand column, the cooling stresses exceed those left after soaking, while in the right column the opposite is true. As is generally known, cooling introduces a negative type of stress, i.e., tension at the cooling surfaces and compression at the central plane. All other things equal, its magnitude is directly proportional to the cooling rate. Accordingly, starting with stress distribution a_1, and imposing a cooling rate equivalent to a_2, we then have, as shown in (b), a distribution equal to their difference. During the cooling itself, stress release will continue in some measure until the temperature has reached such a point that flow ceases, at which juncture we have, as shown in (c), a distribution K × b, meaning some fraction of the (b) distribution. As the temperature decreases further and the cooling rate vanishes, a stress distribution again equivalent to the original rate is regained, leaving a final stress shown in (d). Regardless of the magnitudes of a_1 and a_2, it turns out that the distribution (d) is equal to

$$Ka_1 - Ka_2 + a_2.$$

Now one limiting value of K is zero, signifying complete release during cooling, in which case $d = a_2$. The other limiting value of K is unity, signifying no release at all during cooling, and for this case $d = a_1$. Intermediate values of stress will of course be the rule. Accordingly, it is clear that, for normal stresses, a_1 and a_2 can be regarded as upper and lower stress limits, and if the glass is soaked to either limit and cooled at a rate equivalent to the other, the final stress will be between the two limits. However, K generally tends toward zero,

making d nearer to a_2. Accordingly, cooling at a rate equivalent to the lower limit would lead to the lower stress. But the process also takes longer when this choice is made, so the choice is really not a free one.

It will also be seen from Figure 2 that when $a_1 = a_2$, d also equals either of them. In this case, of course, b = O and K becomes indeterminate and of no consequence. Thus, it is about as effective to make $a_1 = a_2$ and place both a safe distance within the upper stress tolerance, depending on how well the process meets the theoretical criteria discussed earlier. From this point, our considerations will assume that the glass is soaked to bring all tension components to the finally desired limit and is then cooled at a rate equivalent to a stress distribution which, if entirely released, would lead to tensions of this same magnitude. In this way, it can be shown that no final tension stress will exceed the limit.

Figure 3 deals with the special case of pure bending stresses, with cooling taking place from both surfaces and from the bottom surface only. In the second column cooling is from the tension surface and in the third column from the compression surface. Each column is arbitrarily drawn as if K = 0.5, and each results in tensions within the set limit. Among the several interesting differences, we see that cooling from the tension side causes the highest temporary tension but the lowest final tension, while in every case the exposed surfaces end up in compression. This will be true regardless of the value of K in the right hand example, and for all values of K below 0.67 in the other two.

In Figure 4 are drawn similar charts for starting stresses consisting of straight compression and straight tension. Since such stresses are entirely symmetrical, they are drawn for cooling from only one surface. Cooling from both sides could be shown by including mirror images for the other half thickness. These need very little further explanation. We see that the exposed surface is in compression (again requiring K to be less than 0.67 for the right column) and tensions are satisfactory, being on the limit in one case and zero in the other.

It should be pointed out that neither bending nor drumhead stresses can be present except they are supported from other parts of the ware. Even so, they generally exist only in combination with normal stress distributions. However, it can be shown that the same rules hold: if the glass is soaked until all tensions are within the desired limit and then cooled at the rate equivalent to a normal distribution involving that same final maximum tension, there will be no excessive tension in the finished ware.

IV. The Annealing Schedule

In the foregoing discussion, it was stated that various conditions, such as soaking temperature, cooling rate and the like depend upon certain factors such as glass properties and thickness. It now remains to indicate the nature of these dependencies and the means by which one may calculate annealing schedules that will apply under perfectly ideal furnace conditions. To do so requires that the phenomena to be considered be expressed in the form of mathematical laws which are simple enough to be readily solved but at the same time represent the physical facts well enough to be of direct significance.

The Soaking Time. It has been recognized in recent

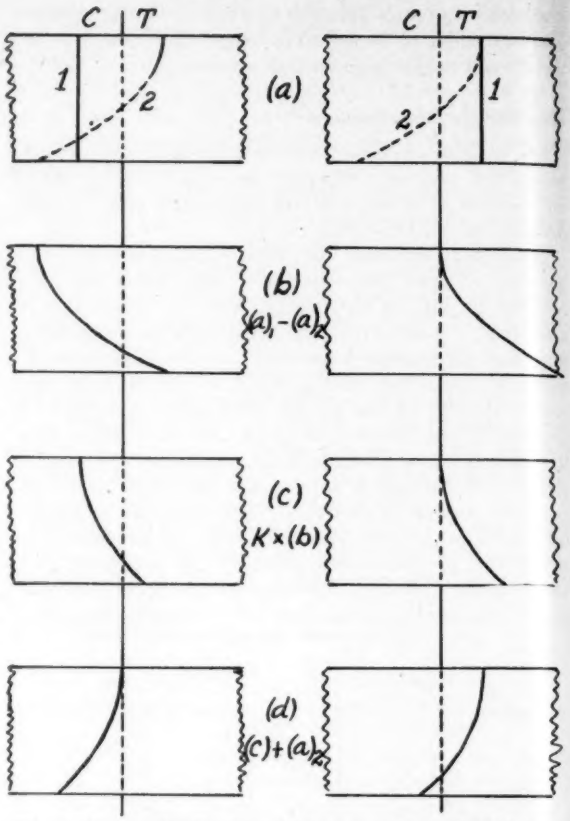

Fig. 4. Stress distributions during annealing. Initial stress "drumhead" type. Cooling from one surface for initial compression and for initial tension.

years that a rather complex combination of effects takes place during treatment at annealing temperatures, so that stress diminishes at a rate determined by physical properties at the same time that the properties themselves are changing progressively toward more stable values. While there is little doubt that future research will clarify this complex situation to the point that the entire phenomenon will be mathematically expressible, we are not at present able to handle it in that way. The best and simplest rule now known, expressing stress release rates, is that put forward several years ago by Adams and Williamson.[4] Although it has been severely criticized on theoretical grounds, its ability to give an accurate empirical picture has never been questioned to the writer's knowledge.

The law results from stress release experiments conducted at constant temperatures in which it was found that after a short initial period the reciprocal of stress increased linearly with time. Since such a relation is simple to handle and has been confirmed in several laboratories, we shall use it here. It can be stated:

$$1/F - 1/F_o = At$$

where F is a stress at time t after starting the stress F_o, and A is called the annealing constant, dependent on temperature.

Since in general, F_o is many times the desired stress level in annealing, the omission of $1/F_o$ from the equation amounts to little more than introducing a small

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NEW IMPACT TESTING APPARATUS FOR BOTTLES AND JARS

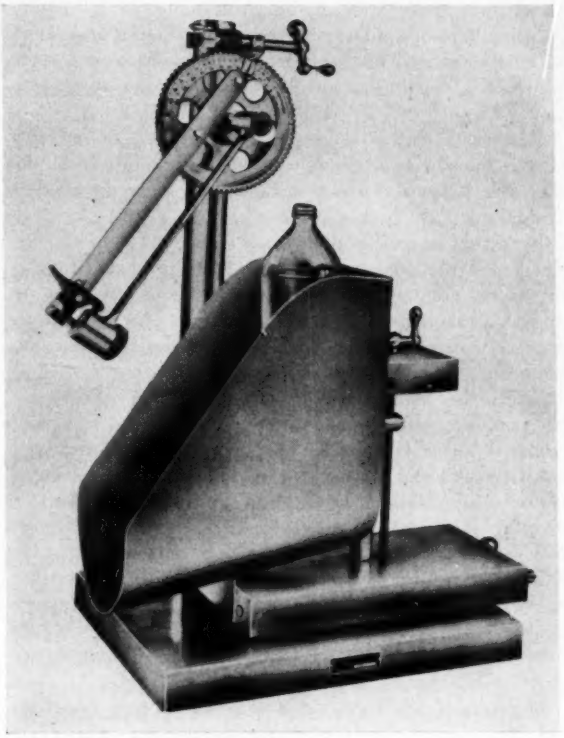
At the request of representatives of a number of glass container manufacturers, the Preston Laboratories' staff has developed a pendulum impact tester for glass bottles and jars, which will shortly be available for general distribution. Several examples of the machine have been out in the factories for some months past, and a fair amount of practical experience of them has been accumulated. In addition, R. E. Mould at the Preston Laboratories has used the device extensively in conjunction with strain-gages for research work on the impact problem, as demonstrated at the Annual Meeting of the Glass Container Manufacturers Institute at White Sulphur Springs, West Virginia, in May, 1950. The impact machine proper is largely the design of J. M. McCormick and is intended to avoid some, or most, of the shortcomings of existing impact testers and to come as near as practicable to simulating service impacts while at the same time giving numerical values of strength that can be trusted. It is also intended to avoid departing too much from the numerical results of existing machines on which extensive data have been obtained. It is further intended to provide a test, convenient and inexpensive, that will deliver accurately reproducible blows under routine testing conditions, unaffected by minor variations in the product tested.

This device, like most impact testing devices, employs a pendulum as the striker because of its simplicity and ease of calibration. The "ideal" pendulum is defined as a heavy mass of very small size at the end of a weightless and inextensible string. Such a pendulum, though it lends itself to calculation and is free from various errors that afflict real pendulums, is quite impractical for the testing of glassware. There has been a tendency, therefore, in the past to depart quite radically from the "ideal" pendulum to get something mechanically tractable, and in the process the fundamental physics of pendulums has sometimes been overlooked. In the McCormick design, an effort has been made to get the practical mechanics and the basic physics into fairly close agreement.

The striking head is a stubby cylinder of steel with a hard steel ball set into one end to do the actual striking. This concentrates the weight behind the point of contact, approaching ideal conditions. The suspension is a thin-walled tube of alloy steel which is quite light but is, at the same time, stiff and strong. In addition, the striking point is offset slightly from the axis of the pendulum head to counteract the effect of the rotational inertia of the head and minimize the twisting and vibration which might occur when a blow is struck.

The blow delivered by the tester can be set readily by a hand crank which determines the height of release. Two scales are provided: one is graduated in inch-pounds of energy available; the other in inches-per-second velocity of the striking head at the instant of contact. Energy is the fundamental unit of impact testing. The velocity scale is useful because the stress set up in the bottles as a result of the impact is very proportional to the velocity, hence equal increments of velocity result in nearly equal increments of stress.

The mass of the pendulum is 1.35 lb., which is comparable with the weight of an average bottle when filled with its contents. It is believed that most bottles are broken by impacts on other bottles; that is, by the collision of two objects of equal mass. The physics of impact, as shown by Mould's work, is considerably affected by relative masses, and this has to be taken into account when the bottle is supported by a backstop. "Backstops" are usual when bottles on a filling line (for instance) collide with one another, and they have also been customary in impact testing in laboratories. It is not possible, or at least not practicable, to vary the pendulum mass for every different mass of bottle, but in general it would not be wise to use as a pendulum a heavy, slowly moving sledge-hammer or a beebee gun pellet at high velocity. They might have equal energies, but the thing that really breaks glassware is the peak force during impact, and the energy is important only in so far as it determines peak force. This may not be the same with pendulums, of widely different character, and the mass chosen in the present tester is a compromise which seems very suitable for many average bottles.



Some people argue for an immovable, infinitely rigid backing-up device. Others suggest no backing at all. Since it is unrealistic to provide no backstop at all (the bottle ought not to be sent flying with every blow), and since nothing can be infinite and still be portable, the Preston machine uses a backstop which is several times the weight of any ordinary bottle and is firmly mounted on a flexible post so that it has the same freedom to move away from every blow.

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IS THERE ANY HOPE FOR THE HANDMADE INDUSTRY?

The immediate future—the next several years—looms dark for large sections of the glass industry. According to present plans, this and a number of other industries will be sacrificed on the altar of an international trade which, the Administration believes, is necessary to prevent war.

It is unlikely that those sections of the glass industry most seriously affected will receive any relief from the executive branch of the government or from the present Congress.

Forceful, logical arguments before the Committee on Reciprocity Information in early June, presented by different representatives of certain sections of the glass industry, were largely a matter of form. The Committee, it is felt, can be depended upon to make recommendations most acceptable to the State Department.

When the Marshall Plan ends, the ECA (Economic Cooperation Administration) nations' officers say, will continue to need about $3 billion worth of products annually from the United States and Canada, as wheat, cotton, and machinery. Imports from ECA nations are running at the rate of about $1 billion a year, and tourism should increase the total of U. S. dollars sent to the ECA nations by some $900 million. Administration spokesmen say that if U. S. imports from these countries could be increased another $500 million, they would have an annual income of U. S. dollars sufficient to pay for the U. S. goods they need.

Glass products have been selected as one of about twenty kinds of products which, authorities say, should enable all the ECA nations to make more U. S. dollars. But, you may ask, why let Czechoslovakia and Poland flood this country with glass products? Several resolutions have been introduced into Congress urging executive action which would rescind any foreign trade agreements with Communist-controlled countries. Most of these bills recommend presidential action based on the opinion of the Secretary of State as to whether or not a country is Communist-controlled. The most recent resolution along these lines, introduced by Congressman Robert T. Secrest of Ohio, aims to place the responsibility of designating a country as Communist-controlled with the Secretary of Defense rather than the State Department since it is felt that the latter would be reluctant to take such official action. The State Department answer is this: Many of the dollars sent to Czechoslovakia and Poland will find their way to ECA nations.

This is the reasoning of Administration officials concerned with foreign trade. It is the reasoning that will prevail unless workers adversely affected by foreign trade can frighten Congress and the Administration into giving them some protection.

Here is what John R. Steelman, Presidential assistant, told a delegation of glass workers from Virginia:

"I cannot be very hopeful of the prospects for United States production of handmade glass to return to the high levels achieved directly after the war. The problem of attracting new industries to replace declining ones is extremely difficult and your district is faced with an unusually critical problem. I am convinced, however, that there is more hope in the direction of attracting new industries than in attempting to support the handmade glass industry except at a reduced level."

There, about as directly as you can get it, is a White House statement abandoning handmade glass to its fate.

It isn't only handmade glass that will suffer. During the hearings before the Committee On Reciprocity Information, Albert S. Crandon, President of the American Window Glass Co., said that freight rates handicap sale of window glass in the Atlantic and Pacific Coast regions. It is cheaper to ship glass from Europe to our Atlantic Coast than it is to ship it by rail or truck from Pittsburgh, he said.

"But," said Earle M. Winslow, Tariff Commission representative on the Committee, "if that is true, how does it happen that the freight rates don't handicap you in foreign markets. The glass industry is exporting much more than it imports."

Mr. Crandon replied that little window glass is being exported now. There has been a marked change in exports since the start of 1950, he said. The records bear him out. Exports averaged $3.7 million monthly in the first four months of 1950, as compared to $4.3 million monthly in 1949.

The point of this exchange is that Administration officials, seeing that glass exports greatly outvalue imports, are convinced that imports can be increased substantially. These officials overlook the fact that very little U. S. glass is going to Europe, and that U. S. exports to other areas are decreasing not only because production costs are higher but also American ocean freight costs are higher.

Mr. Crandon said that window glass from Belgium, Great Britain, and Czechoslovakia is now selling in this country at prices 10 to 30 per cent below American prices.

There is also a distinct threat to cover glass, he said. The tariff on thin glass of 12- to 16-ounces per square foot has been reduced from the 50 per cent of the Tariff Act of 1930 to 30 per cent. During the first quarter of 1950 imports totaled 444,637 pounds, three times the 1949 rate, with half of it coming from Czechoslovakia.

Czech competition was troublesome enough to begin with, but now the Russian Communists have ordered the Czechs to subsidize exports of glass and other products to this country in order to make certain American markets and dollars will always be available.

In glass from 12- to 16-ounces per square foot, first quarter 1950 imports totaled 1,125,000 pounds, as compared to 1,191,626 pounds for all of 1949 and 32,395 pounds for 1948.

That foreign manufacturers are not handicapped by freight rates is evidenced by rates such as the following: From Antwerp, Belgium, thin glass can be shipped to New York City at 44.64 cents per 100 pounds, as compared to a rail rate (Pittsburgh to New York) of 77 cents and a truck rate of 59 cents.

Joseph F. Greene, Manager of Customer Research for the Kimble Glass division of the Owens-Illinois Glass Company, protested against further tariff reductions on products mentioned in Paragraph 217 of the tariff code, particularly borosilicate containers for certain drugs

and unfilled ampuls and vials, and on Paragraph 218 (b) products, glass tubing. Labor costs of these products range from 60 to 70 per cent, he told the committee, and foreign manufacturers are beginning to ship to this country in noticeable quantities and at lower prices.

Eric Walder of Chicago, Illinois, argued against a reduction in the tariff on glass half-tone screens for photo-engraving. A bill is pending in Congress to place quotas on these imports. This bill, like one or two others concerning the glass industry alone, will get nowhere.

The glass industry will never get any place alone in this fight. It is likely that it and the other fifteen-or-so industries affected will not get any place unless they can get some support from CIO unions, as well as from AFL unions.

There were protests, also, against increased imports of optical and ophthalmic glass. Glass products for scientific instruments, it was claimed, certainly merit protection, said Kenneth Anderson, Executive Vice President of the Scientific Apparatus Makers Association.

"It is unthinkable that under present world conditions we should depend on other countries for precision and optical instruments, the tools of the scientist, any more than we should be dependent on foreign sources for military planes, naval vessels, atom bombs, and other instruments of war."

In this country scientific apparatus workers receive $60 for a 40-hour week, as compared to a wage of $16.97 in Britain, and 34 cents an hour in France and Germany, 27 cents in Italy, and 12 cents in Japan. Even skilled foreign workers are very low paid, and as a result some workers in the optical and ophthalmic industries are transferring to other lines.

Of all the glass product industries, the handmade glassware is threatened the most. Listen to what W. L. Orme, President of the Cambridge Glass Company, Cambridge, Ohio, told the Committee:

"Since the export business of our handmade glassware industry has always been a very small percentage of its total business, and now is practically nothing, it seems unfair that we should give up total domestic market and turn it over to these foreign nations with the end result being bankruptcy and thousands of workers thrown into idleness. Other countries are fully employed. Why cut tariffs to help them, particularly when it is American dollars that created the dollar gap by financing all exports to these countries? Since the handmade glass industry has not contributed to the creation of a dollar gap by exporting to these countries, why should it be saddled with the responsibility of closing it by sacrificing its entire domestic market?

"What moral right has the government of this country to force this condition upon us?" asked Mr. Orme.

Mr. Orme belittled the escape clause provisions embodied in reciprocal trade agreements.

"We know of fourteen industries which up to date have appeared and asked for relief, and had very good cases, but have not received any relief," he told the committee.

The labor cost in the handmade glass industry is about 65 per cent of the total, Mr. Orme said, and the break-even point is rapidly increasing to a place where it will be most impossible to operate plants profitably in the face of a declining business.

For the handmade glass industry, and undoubtedly for others, the matter of foreign trade is made worse by the character of the competition that is developing. Orme pointed out that the Glass Manufacturers Federation of England is worried about the Czech competition. He quoted the Federation as saying that the Czechs, in order to meet Japanese competition on sales of chandelier parts in this country, reduced its prices 50 per cent.

It is quite probable that there will be a general tendency to keep imports to this country as low-priced as possible, not because such pricing is necessary to meet American competition but because it may be necessary on the part of one country to meet the competition of another exporter to this market.

Mr. Orme called attention to an effort of the American Flint Glass Workers Union to enlist the aid of other AFL unions in boycotting stores which handle foreign glass products.

RISING COSTS AFFECT BRITISH GLASS CONTAINER INDUSTRY

The biggest problem facing the glass container industry in Britain is the element of rising costs. According to the United Glass Bottle Manufacturers, Ltd., these rising costs have been offset by improved techniques arising from research and from improved handling.

Speaking at the company's Annual Meeting, Harold Judd, Chairman, stated that the average price increase of glass containers has so far approximated 47 per cent over prevailing prices in 1939. Mr. Judd said it was anticipated that they would have to again increase their selling prices, depending upon the Government decision concerning freight rates and other rising costs. The installation of the stem table glass automatic machine unit has proved to be highly successful and Mr. Judd gave credit to the St. Helens management, technical staff, and operatives for the manufacturing success of the venture.

Mr. Judd reported that there has been a steady expansion of the company's output during the years and at present the company requires additional production. Applications for license have been filed for additional buildings and a plant.

JAPANESE GLASS COMPANY BECOMES INDEPENDENT

The Asahi Glass Company, Limited, has announced that it has become independent of Mitsubishi Chemical Industries, Ltd., and returns to its pre-merger status. Asahi Glass Company, Ltd., was established in 1907 and has been engaged in the manufacture of sheet glass, soda products, and refractories.

In 1944, upon its merger with Nippon Chemical Industries, Ltd., it became the Glass and Soda Department of Mitsubishi Chemical Industries, Ltd.

AMERICAN GLASSWARE ASSOCIATION MEETS AT THE GREENBRIER

The 1950 Membership Meeting of the American Glassware Association was held at the Greenbrier Hotel, White Sulphur Springs, West Virginia, June 22 to 24, over 40 members and guests attending.

On the first day of the meeting, the Steering Committee of the Board of Governors met to discuss routine matters of policy and general business, at which C. W. Gustkey, President, Imperial Glass Company, and Chairman of the Board of Governors, presided.

That evening a cocktail and get-acquainted hour was held in the "Old White" Lounge. The General Membership Meeting was called to order after the party, at which Committee and Secretary reports concerning activities for the past year were presented and discussed. A program of possible activities for the coming year was presented and assignments of several subjects for further study and activation were made. Mr. Wayne Greenlee was unanimously elected Chairman of the Nominating Committee for the ensuing year.

On the 23, the Hand Blown and Pressed Table, Stem and Ornamental Glassware Manufacturers met and reviewed tariff activities of the Import Committee and of the officers of the Association. These activities included appearances before the Committee for Reciprocity Information protesting the lowering of tariffs on hand made glassware at Torquay, England, next fall. Need for the industry to actively support the 11 Concurrent House Resolutions now before the Ways and Means Committee which propose rescinding foreign trade agreements and other implements that have been made with Communistic countries was urged. Further plans for presenting the industry opinion to appropriate sources in Washington were also discussed. Other activities pertaining to this section of the industry were presented and assigned to Committees for further consideration and development of plans to activate them.

In the afternoon of the same day, the Automatic Machine Made Tumbler, Table & Kitchen Ware Manufacturers' Executive Committee on Public Relations held a policy meeting concerning the promotion of these wares. The meeting was presided over by William M. Beckler, Sales Manager of Libbey Glass Division of Owens-Illinois Glass Company.

E. A. Hummel, Superintendent of the Colonial National Historical Park at Williamsburg, Virginia, and Mr. Charles E. Hatch, Jr., Park Historian, both of the U. S. Public Park Service, addressed the General Meeting of members and guests that evening. They gave a very interesting talk on the plans of the U. S. Department of Interior to develop Glass House Point, Virginia, which is the site of the first glass factory to be established in this country in the year 1608. This makes glass the first commercially manufactured product in the Western Hemisphere.

Mr. Dean Bowman, Assistant Director of the Industry and Commerce Division of the Bureau of Foreign & Domestic Commerce, Department of Commerce, then addressed the members telling them about the new organization plans of the Department to assist U. S. Industry and the glass industry in particular. A question and answer period following his remarks developed divergent opinion on U. S. foreign and domestic trade policies.

The next morning, June 24, the last day of the meeting, a Joint Contributors and Executive Committee Meeting of Glass Crafts of America was held, Mr. W. F. Dalzell, Chairman of the Executive Committee, presiding. Mr. Erwin Frey of Denson-Frey & Affiliates, who are publicity counselors for this group, outlined past activities of his organization in publicizing handmade glass. He referred to future releases which would be made in television, radio, magazines and newspapers. Following this report, several of the manufacturers told of the results of surveys made among their own sales organizations, which showed the favorable impact the publicity campaign is making on store buyers and consumers. Further information was stated by representatives of the U. S. Public Park Service regarding the intimate details on the restoration of Glass House Point in which this group was particularly interested. Other routine financial and general policy matters were discussed.

The General Membership Meeting formally closed after lunch and it was the general opinion that this gathering had offered an opportunity for all members of the pressed and blown glassware industry to become better acquainted both socially and in a business way and that future meetings of similar character be encouraged.

Standing, left to right: T. Clarence Heisey, President, A. H. Heisey & Company, Newark, Ohio; John C. Weber, Jr., Sales Manager, West Virginia Glass Specialty Co., Weston, West Virginia; W. C. McCartney, Secretary & Sales Manager, The Cambridge Glass Company, Cambridge, Ohio; Erwin M. Frey, President, Denson-Frey & Affiliates; seated, left to right: H. L. Dillingham, Executive Secretary; Carl W. Gustkey, President, Imperial Glass Corporation, Bellaire, Ohio; William F. Dalzell, President, Fostoria Glass Company, Moundsville, West Virginia; Henry E. Payne, President, Dunbar Glass Corporation, Dunbar, West Virginia.

CONTINUOUS AUTOMATIC GAUGING FOR TUBING LINES

By J. N. SWARR, Consulting Engineer

Practically all applications of glass rod or tubing require that the outside diameter be held within relatively close tolerances. Specifications usually stipulate the diameter and tolerances as measured approximately six inches from one or both ends of each piece. In order to meet these customer specifications, the usual practice in the rod or tubing manufacturing plant is to maintain a Gauging and Sorting Department to which the ware is transported from the draw machines. Here the outside diameter of each piece is checked at one or both ends, as required, with a Go-no-go gauge and those pieces which are found to exceed the prescribed tolerances are rejected. This method obviously requires a large amount of man power and is therefore very costly. The extra handling involved results in considerable breakage of acceptable product which adds to the cost of the operation. The space requirements for this department also contribute to the total cost of production. Furthermore, manual, one or two point gauging leaves much to be desired in the quality of the selection. The pieces being gauged are normally five feet in length whereas the end use of the ware will require that those lengths be cut into smaller lengths which may range from as short as one inch. The outside diameter of the tubing, as it is drawn, varies continuously and a one or two point check in a five foot length is no assurance that the entire length of an accepted piece is satisfactory for the end use for which it is ultimately intended. At best, manual gauging is subject to normal human errors.

In order to reduce, or completely eliminate, the high cost and other undesirable features of manual gauging, the idea of continuous automatic gauging and selection was conceived. The installation of this completely automatic system is illustrated in Figure 1. The servo-gauge, which is the basic outside diameter measuring element, is mounted on the line so that the tubing passes through it on its way to the draw machine. Thus every increment of length is measured, and if any portion of any piece exceeds the prescribed tolerances, that piece is automatically rejected when it reaches the sorting table, as explained below. Thus all gauging and sorting operations are performed without any manual assistance or attention. The selection is infallible in its accuracy and dependability, and the undesirable extra handling is completely eliminated. By preventing the excess breakage which results from the extra handling, the total weight of glass packed has been found to be greater where the automatic system is used, even though continuous gauging rejects more pieces.

Operation of System

The complete Servo-Gauge system consists of four separate components, the operation and function of each of which is explained in detail as follows:

1. Continuous Measuring Element: In line with accepted practice in modern production gauging and in industrial instrumentation in general, the measuring element is built around a pneumatic servo-mechanism. The wide spread acceptance and use of this principle is due to the fact that its zero stability and its range stability are inherent, whereas electrical or electronic devices have no inherent zero stability and frequently no range stability. Moreover, the output of the pneumatic servo-mechanism is linear with respect to the measurement, whereas the output from most electrical elements is not.

Figure 2 illustrates the basic principle of operation of the particular form of servo-mechanism employed in the Servo-Gauge system. 1 and 2 are metallic bellows, shown in cross section, which are mounted concentrically and attached at the top to a fixed base 9. They are attached at the bottom to a movable disc 5 which is urged upward by spring 6. The annular space between the two bellows is connected to atmosphere through tube 8 which is capped by a small nozzle 3. Compressed air, nominally supplied at 20 psi, passes through a small restricting orifice 4, and then into the annular space between the two bellows from which it exhausts to atmosphere through tube 8, and nozzle 3. Orifice 4 is much smaller than nozzle 3, and the pressure between the bellows is therefore normally at atmosphere and the bellows and nozzle assembly is in the extreme upward position.

Any increase in the air pressure within the bellows system will produce a downward force on disc 5, which will cause the assembly to move downward against the force of the spring. Equilibrium will be established when the downward force due to the air pressure, exactly equals the upward force of the spring. The assembly will remain in this equilibrium position until a change in air pressure causes it to shift to a new equilibrium position.

The relation between these forces is given by

$$dK = PA$$

Where d is the downward movement of disc 5 from its zero position

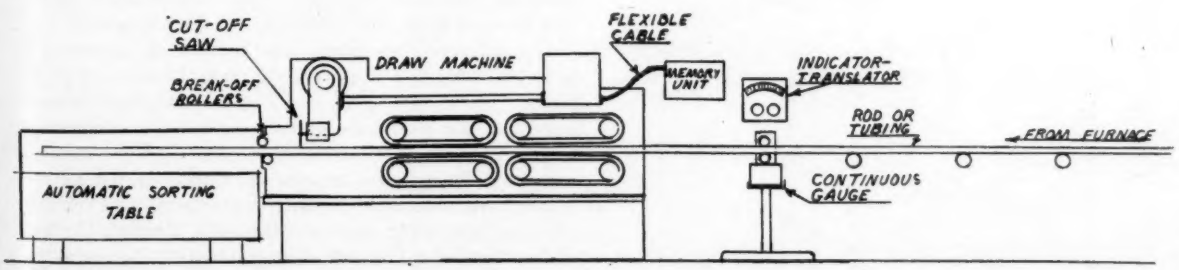


FIGURE 1- DIAGRAMMATIC APPLICATION OF SERVO-GAUGE SYSTEM

K is the combined spring rate of spring 6, and of bellows 1 and 2.

P is the air pressure between the two bellows

A is the effective area of the bellows assembly. It is the difference between the effective areas of the two individual bellows.

Since A and K are both fixed and constant, the downward movement is directly proportional to the air pressure.

As pointed out above, the natural condition of the system is that of zero pressure between the two bellows, in which case the bellows and nozzle assembly is in its extreme upward position. Air is then discharging to atmosphere through nozzle 3 at a rate determined by the size of orifice 4. If now, any plane surface such as 7 (called the flapper in instrument terminology) is made to approach nozzle 3, there will be no change in the system until the spacing between the nozzle and flapper is reduced to about .003 inches. If the flapper is moved closer than about .003 inches, the flow of air to atmosphere is restricted and the pressure in the space between the two bellows increases. This causes the assembly to move downward, as explained above, which motion again increases the flapper to nozzle spacing. This downward motion of the nozzle will cease when the spacing again becomes approximately .003 inches. Thus, as the flapper is moved toward the nozzle, the system will always act to move the nozzle away from the flapper so as to maintain an essentially constant spacing of .003 inches between the two members. Conversely, as the flapper is moved away from the nozzle, the system will move the nozzle toward the flapper to maintain this essentially constant spacing. Thus the movement of the bellows assembly is always equal to the movement of the flapper. This being true, d in the above equation can be redefined as the downward movement of the *flapper* from its zero position, the zero position being that beyond which the nozzle system follows the flapper movement.

Rewriting the above equation gives the relation

$$P = d\,\frac{K}{A}$$

which shows that the pressure developed in the system is directly proportional to the movement of the flapper. The actual relation between P and d (which relation is the range of the instrument) is shown to be determined

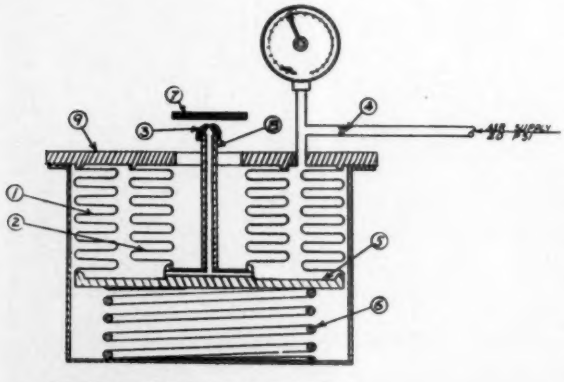


FIGURE 2- OPERATION OF SERVO-GAUGE

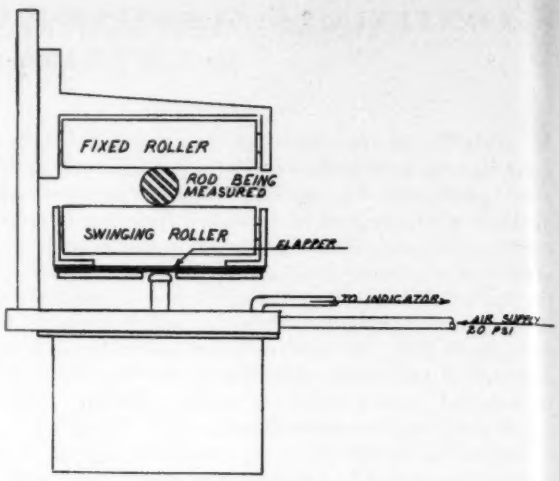


FIGURE 3- SERVO-GAUGE ON TUBING LINE

by the ratio of the spring constant to the effective area of the bellows assembly. By selecting the proper values, instruments can be designed which will produce a 20 psi pressure change for several inches flapper movement or for several thousandths inches, as desired. Because this mechanism is completely free of friction and lost motion of any kind, and because the force required to move the flapper is infinitesimal, it possesses inherently all of the characteristics required in a high precision measuring element. Its sensitivity is limited only by that of the pressure measuring device employed with it. If a manometer is used, variations of .00001 inches are readily measured.

Figure 3 illustrates diagramatically how this basic unit is incorporated into the design of the Servo-Gauge for high precision measurement of tubing diameters. The upper roller is fixed in position relative to the fixed element 9 of the bellows assembly. The lower roller is urged upward by a spring (not shown) which maintains the roller in contact with the tubing being measured, which tubing, in turn, is thereby maintained in contact also with the upper roller. Therefore, as the diameter changes, the lower roller changes its position relative to the fixed element 9 of the bellows system. The flapper is attached to the lower roller assembly and moves with it. It is shown as the shaded strip beneath the bottom roller and just above the nozzle. Thus as the diameter changes, the motion of the flapper toward or away from the nozzle produces changes in air pressure which are exactly proportional to the changes in diameter.

In order to permit the gauge to accommodate a wide range of diameters, the upper roller can be shifted manually, up or down, by loosening two thumb screws.

II. Indicator-Translator: The function of this element is to indicate, on a large, easy-to-read dial, the actual diameter being measured, and to complete an electrical circuit to the automatic sorting mechanism whenever a tolerance is exceeded. Since the measured diameter is converted into a proportional air pressure, the indication of the diameter can be provided by any reliable pressure measuring element. By using the helical form of bourdon tube, the indicating pointer can be connected directly to the end of the tube, thereby providing an element which is without links and pivots and therefore en-

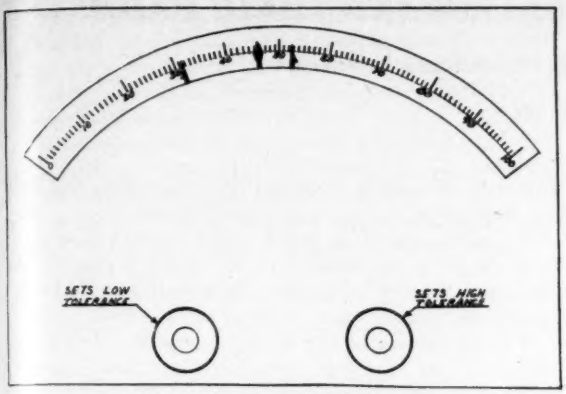


FIGURE 4 - INDICATOR-TRANSLATOR ADJUSTMENTS

tirely free of friction and lost motion. The control function is readily performed by providing electrical contacts which are manually set to close whenever either the high or low tolerance is exceeded.

Figure 4 shows the general arrangement of this unit with its dial, indicating pointers, and tolerance adjusting knobs. Of the three pointers appearing on the indicating scale, the one in the middle indicates variations in diameter and is therefore in more or less continuous motion when the unit is in operation on the line. The other two pointers define the tolerances and are manually set to the desired values by turning the two knobs. Turning the left hand knob sets the pointer on the left to the lower tolerance for the particular specification being run, whereas the right hand pointer is set to the upper tolerance by turning the right hand knob. When the measured diameter is between these two limits, the piece passing through the gauge is accepted. When the diameter reaches or exceeds either of these limits, the piece is automatically rejected when it reaches the sorting table, as explained below.

This unit is normally mounted in a position close to the line operator. By providing a large indicating scale, the operator is constantly informed regarding the size being produced so that he can make the necessary adjustments to keep the line on size. A recording instrument can be supplied in place of, or to supplement, the indicator. The recorder is useful in that it shows trends as well as instantaneous readings. This permits an alert operator to make corrections before off size ware is produced. It is sometimes desirable to have one recorder at the draw machine and another at the furnace end of the line, both, of course, operated from the same Servo-Gauge.

III. Automatic Sorting Table: The principle of the automatic sorting table is very simple, as shown in Figure 5 which is self-explanatory. The tilting section is operated by an electro-pneumatic piston which receives its impulses from the Memory Unit as described below. The detailed design of this table varies to meet the individual requirements of the plant in which it is to be used.

IV. Memory Unit: Obviously, the basic principle of continuous gauging requires that the measurement be made on the continuous line, rather than on individual pieces after they have been cut to length. Theoretically, it would be possible to perform the function of automatic sorting if the diameter measuring element were mounted at the point where break-off occurs. However, there are practical reasons why it is undesirable to mount any gauging device anywhere on the draw machine. In fact the only practical location is somewhere ahead of the machine. This means, however, that each piece is measured at a point which is some distance ahead of that at which it is cut and sorted. This does not impose any particular problem. It required only that the impulses from the gauge and Indicator-Translator, resulting from an off-size piece, be mechanically withheld from the sorting table until the piece which created the impulse reaches the table.

Figure 6 shows diagrammatically the mechanism and circuit by which an impulse can be "stored" in the Memory Unit and released at the proper instant. A basic requirement is that the gauge be located a whole number of piece lengths upstream from the break-off point. With most machines this is two or three lengths. For example, if 62 inch pieces are being produced, the rollers of the Servo-Gauge must be either 124 or 186 inches upstream of the break-off point. The case illustrated is that in which the gauge is located three piece lengths upstream. Thus, at the instant just preceding a break-off, there are four pieces on the line downstream of the gauge. This requires a Memory Unit made up of four separate sections, each operating with a phase difference of 90 degrees. Cams I to VIII are all mounted on one cam shaft which is driven through a flexible cable by the cut-off saw drive of the draw machine. Thus the Memory Unit is tied directly to the device which defines the pieces so that the entire unit remains perfectly synchronized. The speed of the cam shaft is such that it rotates through exactly 90 degrees while one piece length passes through the measuring element.

The pieces spoken of here as passing through the measuring element are imaginary to the extent that they are neither cut to length nor marked in any visible manner. They are, however, clearly and precisely defined by the relative locations of the break-off point and the gauge. If these are 186 inches apart, and the line is adjusted to produce 62 inch lengths, the particular ele-

(*Continued on page* 384)

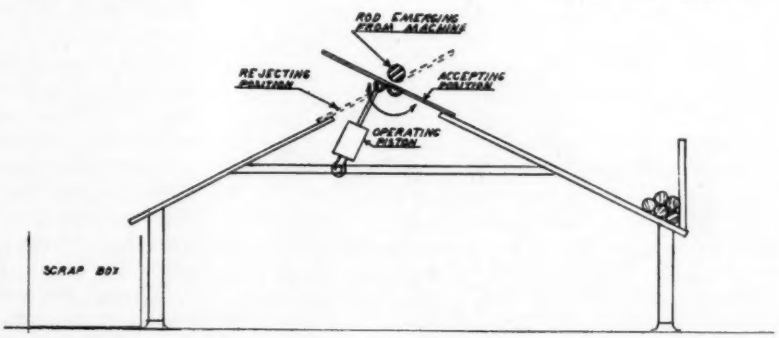


FIGURE 5 - DIAGRAMMATIC END VIEW OF AUTOMATIC SORTING TABLE

THE NATURE OF GLASSES AND GLAZES AND THEIR HARDNESS

By DR. FELIX SINGER, Consulting Ceramist

PART III

Recent X-Ray Diffraction Work on Oxide Glasses

(*A*) *Glasses Based on Silica* (SiO_2): The work of Warren and his associates has brought excellent experimental confirmation of Zachariasen's theory of glass. The action of monochromatic X-rays upon crystals produces a number of sharp diffraction lines or spots due to diffraction by the three-dimensional crystal grating. The action of monochromatic X-rays on gases, liquids or glasses on the other hand produces one or a few broad diffraction bands. From such bands it is, however, possible to calculate average interatomic distances and, in favorable cases, approximately the number of atoms at such distances. The experimental refinements used by Warren were the use of crystal monochromatized X-rays and of vacuum cameras and, in the interpretation, the use of radial Fourier distribution analyses.

Fig. 3 shows a schematic two-dimensional arrangement of SiO_4 tetrahedra, represented by three oxygens (open circles) around each silicon (full circles). With a lowering of the temperature, there is probably not much change in Si-O distances but slight changes in bond angle, indicated by the arrows in "a", allow the arrangement "b" to be obtained. Such an effect, aptly called by Warren a "cooperative manoeuvre", can only be obtained in regular, crystalline patterns.

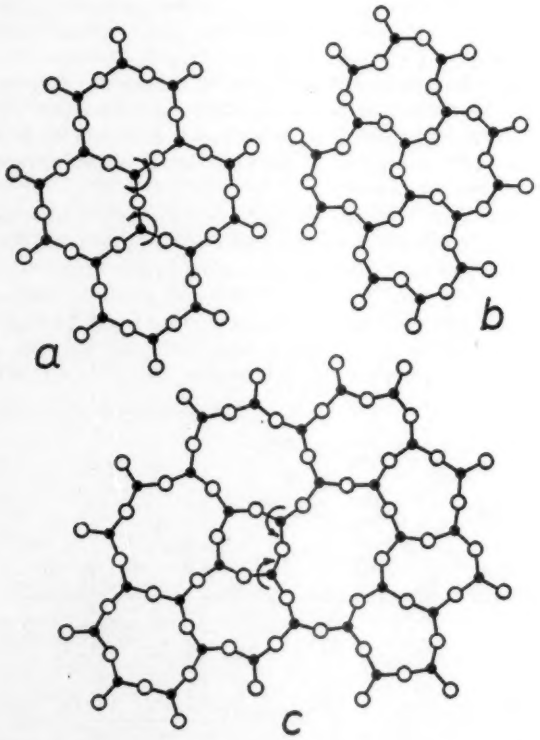


Fig. 3. Schematic two-dimensional figures to illustrate the difference between the regularly repeating structure of a crystal and the random network of a glass. a and b, crystalline structures; c, glass.

A similar change in bond angles upon a change of temperature is not possible in "C" which represents the random network of the glass. Here strains could be set up but no over-all volume change would result.

Warren's data also disproved the opposing theory that vitreous silica consisted of cristobalite crystals of very small grain size. X-ray diffraction lines due to the interaction of monochromatic X-rays and crystals are, in general, sharp, but they do get wider if the crystals are of extremely small size. The diameter of cristobalite crystals which can be calculated from Warren's data is only about 7 Å, so that the "crystals" would only contain a few silicon-oxygen tetrahedra. Under such conditions the term "crystal" becomes meaningless.

Fig. 4 shows a schematic two-dimensional diagram where the shaded circles correspond to Na, K or Ca. Since the introduction of Na_2O, K_2O, CaO in the system increases the oxygen content, it will be true that every silicon is bonded to four oxygens, but only a part of the oxygens will be bonded to two silicons, the remainder to one silicon and to another cation. This weakens the strength of the system, lowers the softening point and increases electric conductivity, which is of the electrolytic types, increasing with a rise in temperature.

(*B*) *Oxide Glasses Containing Boric Oxide* (B_2O_3) *and/or Alumina* (Al_2O_3). In similar work, Warren found boric oxide glass to consist of a network of boron atoms in three-fold coordination with oxygen, the B-O distance was 1.39 Å while in crystalline borates, the B-O distance showed an average of 1.36 Å. The number of oxygens deduced from the peak was 3.1. However, glasses in the system Na_2O-B_2O_3 showed a small increase in the boron-oxygen distance and in coordination number, which Warren explained in the following way:

In boric oxide glass the $(BO_3)^{-3}$ units form a random three-dimensional network, every oxygen being linked to boron ions. Upon the addition of small amounts of Na_2O the oxygen boron ratio increases and it is now possible for some of the borons to be surrounded by four oxygens. This effect ceases after a given amount of sodium (about 13 per cent) has been added. The reason is that such an arrangement will lower the free energy of the system. The first sodium atoms added will have the tendency to be surrounded by six unsaturated oxygens, and $(BO_4)^{-5}$ tetrahedra produce four times as many unsaturated oxygens as $(BO_3)^{-3}$ triangles.

I have summarized W. A. Weyl's opinion about the similarity of alumino silicates and boro-silicates. Now, after explaining in detail the boric oxide anomalies, I come back to the reported alumina anomalies by again citing Weyl.[10]

"From a chemical view point the alumino silicates are similar to the boro silicates. Like B^{3+} in boro silicates, the Al^{3+} forms tetrahedra only in the presence of alkali or alkaline earths. In alumino silicates we have to expect a phenomenon similar to the boric oxide anomaly.

Both classes, alumino silicates and boro silicates, have in common the fact that they contain ions which readily change from one state of coordination to another."

"Addition of Al_2O_3 therefore, makes a sodium silicate glass resemble one of higher acidity."

Weyl's expectation of an alumina phenomenon, "similar to the boric oxide anomaly" have come true. And he himself adds another example of similarity:[10]

"For the glass melter one fact should be of particular interest. Both ions have a tendency to retain any OH^- and fluorine ions which may be present in the melt. The relatively high water content and the difficulty of refining boro silicate and alumino silicate glasses can partly be attributed to this tendency. The high solubility and stability of fluorides in alumino silicate glasses is a direct consequence of the ability of the Al ion to tie up OH^- and F^-. This tendency expresses itself not only in glasses, but also in crystals."

Weyl reports here only the effect of B and Al ions on fluoride-containing glasses. However, exactly the same experience is known with ceramic glazes: the phenomenon described makes the development of smooth glazes, free from pinholes very difficult and requires careful consideration.

Weyle reports further:[10]

"Long before the structural reasons were known, the glass technologist has taken advantage of the strengthening effect of the aluminium ion. If alumina is introduced into a soda-lime-silica glass its chemical resistivity and viscosity are considerably increased, and simultaneously its strengthening of the glass structure prevents devitrification."

The position of the ceramist at this point has been mentioned before:[8]

"Alumina has long been recognized as the oxide which has the greatest effect on durability, and it is now very rare to find glazes in which it is not present. The modern highly resistant glazes owe their valuable properties largely to alumina."

Weyl's report on glass:[10]

"Of great importance is the influence of alumina on the solubility and rate of solution of opacifying agents such as TiO_2 and SnO_2."

is very well known to the ceramist who takes advantage of this knowledge for the development of the most efficient opaque Bristol Glazes.[27]

In a schematic design in two dimensions Biscoe and Warren[28] describe the structure of a soda-boric oxide glass with a low soda content. They assume that each boron is bonded either to 3 or 4 oxygens, the fraction in tetrahedral coordination increasing with an increase in soda content. This figure is only schematic in that the tetrahedral groups are shown with all 4 oxygens on the same plane. For low soda content each oxygen is bonded between 2 borons. The boron and oxygen atoms form a random network in which the boron coordination is partly triangular and partly tetrahedral. The nature of this network is therefore intermediate between the tetrahedral network of vitreous silica and the triangular network of vitreous boric oxide. It is an open-type network, with holes between the oxygens of the right size to accommodate a sodium ion. The sodium ions are arranged at random in these gaps of the network, with each sodium surrounded on the average by about 6 oxygens.

Biscoe and Warren compared the arrangements of the

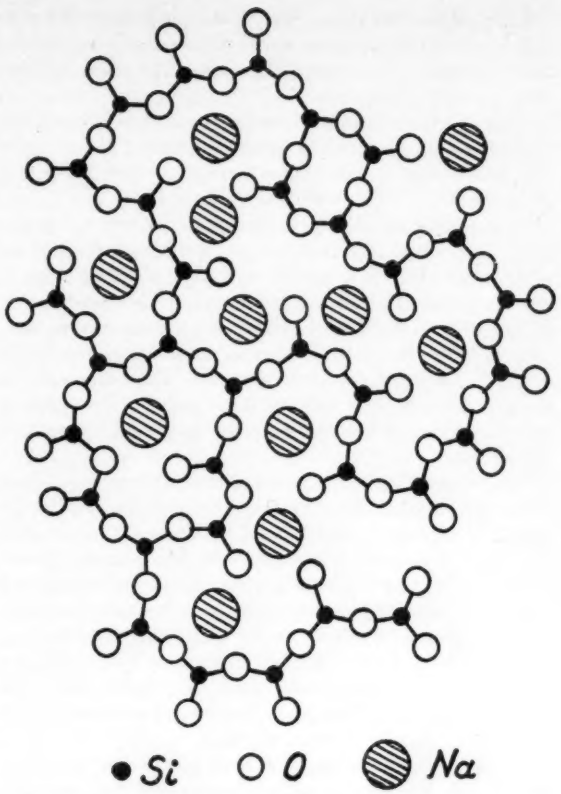


Fig. 4. Schematic representation in two dimensions of the structure of soda-silica glass. To correspond to two dimensions, the silicons are shown bonded only to three oxygens.

sodium ions in the network holes either in a soda-boric oxide or a soda-silica glass to the scheme of structure in a feldspar and found complete analogy of these. In a feldspar crystal, the silicon, aluminum and oxygen atoms form an open tetrahedral network, and the alkali and alkaline earth atoms are arranged in the spaces in this network. Biscoe and Warren emphasize that the oxides do not exist as molecules in the glass, but the sodium ions, Na^+, are situated in the holes in the boron-oxygen network.

The most interesting result of Biscoe and Warren's study is the possibility to explain now the so-called "boric oxide anomaly": They found that with increasing soda content, more and more of the boron atoms go over from triangular to tetrahedral coordination. By this ability of the boron atom to change from triangular to tetrahedral coordination, the maxima and minima in physical properties of glasses containing boric oxide and soda can be explained. The condition is the presence of an oxide, such as Na_2O, able to supply the necessary extra oxygen. However, there is a limit: beyond about 16% Na_2O, the tendency for the borons to change over to tetrahedral coordination begins to fall off, and transition is no longer complete because triangular coordination is the normal one of the boron atom. Only special conditions will force it into tetrahedral coordination: With further increase in soda, the additional oxygens are no longer completely taken up by borons changing over from triangular to tetrahedral coordination. Some oxygens will be bonded only to one boron. To represent

the structure at this stage the figure must be modified so that some of the oxygens are bonded only to one boron. The number of these single-bonded oxygen will increase with mounting soda-content.

This produces breaks in the boron-oxygen network and a decrease in the strength of the structure. The greater the number of single-bonded oxygens, the looser the structure.

If the addition of soda to the glass is only a few per cent, part of the borons change over to tetrahedral coordination. The BO_4 groups are bonded to the rest of the structure in four directions, and the structure is therefore tied together in three dimensions rather than only in two. This will produce a marked increase in the strength and tightness of the structure. The forces of attraction between the sodium ions and the surrounding oxygens will also contribute to the increased strength of the structure.

The arrangement of boron and oxygen can be assumed to be the same as that of silicon and oxygen in vitreous silica. If vitreous silica is used with the oxygens undisturbed, each silicon is replaced by a boron and for each boron one sodium ion is introduced into a network space, a hypothetical $Na_2O \cdot B_2O_3$ glass would result. In making this change, there would be a shrinkage in volume, owing to the fact that the Si-O distance is 1.62A and the tetrahedral B-O distance calculated is about 1.50A. The density of this hypothetical glass can be calculated in terms of the density of vitreous silica.

The same consideration explains the fact that the addition of soda produces exactly opposite effects if added to boric oxide or if added to silica. As described before, when a few per cent of soda are added to boric oxide, part of the borons are changed over to tetrahedral coordination and are tied to the rest of the structure by four bonds rather than three. This increases the strength of the glass or, in other words, produces a harder glass. On the other hand when soda is added to silica the opposite effect occurs. Silicon does not show the ability of boron to change its coordination number. The coordination number of silicon is always four, each silicon being tetrahedrally surrounded by four oxygens. With the additions of soda, the oxygen-silicon ratio requires that part of the oxygens be bonded only to one silicon, thus producing breaks in the silicon-oxygen network. Because the strength of the structure is mainly in the silicon-oxygen network, the more of these breaks, the looser or weaker the structure.

In soda-boric oxide-silica glasses, many physical properties reach their maxima or minima as a function of the composition. Some of these are so well known by numerous measurements that many details can be calculated in full agreement of theory and practice. For other properties we have a qualitative judgment and are studying the theoretical possibilities to be used for further improvements.

It was reported above[3, 24, 25] how the hardness (resistance to scratching) of glasses and glazes can be improved by introducing minor constituents into the composition. The theory by Biscoe and Warren[28] explains why boric oxide produces the greatest improvement of hardness in glasses and glazes and allows us to understand the practical improvements by alumina. However, we are not yet so far as to calculate the hardness of a glass from its composition but we might achieve this progress by further research. In this way we try to understand "what is hardness"?

It is relatively easy to define the hardness of glazes generally as their resistance to scratching in ordinary use, for example in form of dinnerware plates in restaurants, etc. However, for the understanding of the problem to improve this quality, it is important to explain the question "what is hardness" from a wider angle.

Heinrich Hertz[29] defined hardness as the pressure just necessary for an indentor to exceed the elastic limit. This process can take place with different materials in two ways: brittle materials break, flexible ones adjust themselves. Based on Hertz's theory, Anorbach has developed a method for measuring hardness. He denoted as "absolute hardness" the pressure in kg per square millimeter necessary to break a disc made from the material to be tested by a ball from the same material, if the pressure is slowly increased. At a certain point the disc breaks in form of a circle, the diameter of which in combination with the pressure applied serves for the calculation in accordance with Hertz's formulae. Determination of the absolute hardness is, however, very difficult and takes a long time: therefore it is not used very often and the procedure in practice is still the old method of Mohs. The latter is based on the selection of a series of minerals serving as a scale, the softest, No. 1, being scratched by No. 2 and so forth. No. 2 being scratched by No. 3 and each following mineral but not by No. 1. In this way it is possible to determine the resistance against scratching of a test material which lies between the hardness of two well-known minerals. It must be emphasized that this Mohs' scale is only an indicative but not a quantitative one. It can be seen from the following table of Mohs that the difference between Nos. 9 and 10 is greater than between No. 1 and 9. It is for this reason that the Mohs scale has been extended:

Mohs' Scale	Extension of Mohs' Scale[30]
(1) Talc	(1) Talc
(2) Gypsum or rock salt	(2) Gypsum or rock salt
(3) Calcite	(3) Calcite
(4) Fluorspar	(4) Fluorspar
(5) Apalite	(5) Apalite
(6) Orthoclase	(6) Orthoclase or Periclase
(7) Quartz	(7) Pure vitreous silica
(8) Topaz	(8) Quartz
(9) Sapphire	(9) Garnet
(10) Diamond	(10) Topaz
	(11) Fused Zirconia
	(12) Fused Alumina
	(13) Silicon Carbide
	(14) Boron Carbide
	(15) Diamond

However, even this extended scale only permits a qualitative judgment of hardness, a certain comparison.

Apparatus have therefore been built which allow to be measured more precisely (Martens). In this method a diamond point under continuous load is pulled across the material to be tested and the width of the scratch is measured. Another way is to change the load of the diamond pin necessary to achieve the same width of the scratch. A great number of variations of these devices

have been developed and are being used successfully.

One fact has to be borne in mind for all these methods. Scratching means the destruction of the lattice of one material with the lattice of another material, the better remains intrinsically undamaged. (Other methods of measuring hardness, mainly used in engineering based on elastic compression, are not discussed in this essay.)

Ernest Friederich[31] found the connection between electrostatic behavior and physical properties, especially the hardness of materials. V. M. Goldschmidt[32] showed that resistance to scratching depends on atomic proximity, distance of the particles, the valency. He investigated materials which possess ionic lattices and the following two tables are taken from his work.[11]

		Mg	*Ca*	*Sr*	*Ba*
O	Particle distance ..	2.10	2.40	2.57	2.77
	Mohs hardness	6.5	4.5	3.5	3.3
S	Particle distance	2.59	2.84	3.00	3.18
	Mohs hardness	4.5-5	4.0	about 3.3	about 3
Se	Particle distance	2.74	2.96	3.12	3.31
	Mohs hardness	3.5	3.2	about 2.9	about 2.7
Te	Particle distance	—	3.17	3.32	3.49
	Mohs hardness	—	2.9	about 2.8	2.6

In the following table by Goldschmidt, materials are compared in pairs which differ in their ionic changes.

	LiF	*MgO*	*NaF*	*CaO*	*LiCl*	*SrO*	*NaCl*	*BaO*
Particle distance.	2.02	2.10	2.31	2.40	2.57	2.57	2.81	2.77
Mohs hardness ..	3.3	6.5	3.2	4.5	3	3.5	2.5	3.3

	LiCl	*MgS*	*NaCl*	*CaS*	*Li Br*	*MgSe*
Particle distance	2.57	2.59	2.81	2.84	2.75	2.74
Mohs hardness	3	4.5-5	2.5	4.0	2.5	3.5

	NaBr	*CaSe*	*KCl*	*CaTe*	*Kj*	*BaTe*
Particle distance	2.98	2.96	3.14	3.17	3.53	3.49
Mohs hardness	2.4	3.2	2.3	2.9	2.2	2.6

Goldschmidt gave a further proof of Friederich's theory in the following tables, showing partly free elements in crystals of the diamond type, partly compounds in crystals of the wurtzite-zinc-blende type.

Valency	*1*	*2*	*3*	*1*	*2*	*3*	*4*
	Ag J	*Cd Te*	*InSb*	*Cu Br*	*Zn Se*	*Ga As*	*Ge Ge*
Particle distance	2.81	2.80	2.79	2.46	2.45	2.44	2.43
Mohs hardness.	1.5	2.8	3.8	2.5	3-4	4-5	6

Valency	*1*	*2*	*3*	*3*	*1*	*2*	*3*	*2*
	Cu Cl	*Zn S*	*Ga P*	*As Al*	*Cu J*	*Zn Te*	*Ga Sb*	*Se Cd*
Particle distance	2.34	2.35	2.35	2.44	2.62	2.64	2.64	2.62
Mohs hardness ...	2.5	4	5	5	2.4	3.0	4.5	3.0

Valency	*3*	*4*
	Al P	*Si Si*
Particle distance	2.36	2.35
Mohs hardness	5.5	7

Goldschmidt closes these examples with two groups in which the constancy of distance between particles is less obvious:

Valency	*2*	*4*	*2*	*3*
	BeO	*CC*	*CdS*	*SbAl*
Particle distance	1.65	1.54	2.52	2.64
Mohs hardness	9	1.0	3.2	4.8

These tables show a strong increase in the hardness with increasing valency of the participating particles. Goldschmidt emphasized the particular case of the free element carbon, silicon and Germanium. It was Friederich who showed that hardness of elements follows the same regularity as hardness of simple compounds. They all depend on the kind of linkage which also decides the valency and melting point both of crystals and glasses. Goldschmidt went a step further. He described how to make "models of crystals" which are weaker than others and expressed his belief that it would be possible also to make crystals and glasses with stronger physical properties, greater hardness, higher melting point, etc. He gave examples for special cases. He was of the opinion that from the atomic closeness of glasses and glazes, the packing density and thereby their hardness, their resistance to scratching could be calculated. Goldschmidt[a] thought that scratch resistance of glazes was not mainly dependent on the silica content, the increase of which increases, in most cases, the melting point but could be improved for low melting glazes by the right combination of silicate and borate and possibly phosphate glasses and glazes. Newer research on the constitution of glasses shows how this aim might be achieved. It has been known for a long time (1926)[33] that some of the most common constituents of silicate glasses increase the resistance against scratching in the following order: Boric oxide, alumina, barium oxide, magnesia, zinc oxide.

After the explanation of the anomalies of boric oxide and alumina, we know that each of these constituents does not possess one "coefficient of hardness" but produces an optimum, which must change in relation to all other ingredients. The resistance of glazes against scratching does not depend only on the glass to which the glaze might be fused but, at least to the same extent on the smoothness of the surface, its brilliancy, pinholes and other defects, stresses which might lead to crazes, etc.

(c) Glasses based on Phosphorous Pentoxide (P_2O_5): X-ray data have been given for two glasses in the system CaO-P_2O_5. The radial distribution curves confirm the tetrahedral arrangement with a P — O distance of 1.55Å. The Ca-O and O — O distances are not separated, but it can be estimated that calcium is surrounded on an average by seven oxygen atoms. The P — P distance is smaller than twice the P — O distance, leading to a bond angle P-O-P of about 140°. In comparing sodium glasses with calcium glasses, in general it can be said that calcium glasses will be less stable because the higher charge of calcium will favor a crystal line arrangement, but in comparing calcium silicate with calcium phosphate glasses, the latter will be more stable. They have a higher oxygen network-forming cation ratio and are therefore in a better position to supply the necessary amount of unsaturated oxygens for the calcium ions.

Kreidl and Weyl[34] have given very valuable details about the structure of phosphate glasses. They point out that on the basis of the ratio of oxygen to network-forming cations phosphorous pentoxide P_2O_5 is comparable to $Na_2Si_2O_5$ and that thermal expansion, softening point and chemical resistance, which depend on the network itself, are very similar in both glasses. Optical and electrical properties, however, depend essentially on the network modifying ions and in these properties P_2O_5 is similar to SiO_2 glass. Aluminium orthophosphate $Al\,PO_4$ forms a glass which can be considered as vitreous silica in which the silicons are replaced, alternatively, by aluminium and phosphorous. Every student of qualitative

(*Continued on page* 386)

[a] Personal information from the late V. M. Goldschmidt.

President-Elect Howard R. Lillie (left) of The American Ceramic Society with Society Secretary Charles S. Pearce, boarding a London-bound Pan-American Airways Stratocruiser at New York's International Airport.

HOWARD R. LILLIE LEAVES FOR EUROPEAN GLASS MEETINGS

Howard R. Lillie, research physicist for Corning Glass Works and President-Elect of The American Ceramic Society, flew to London from New York June 24, on the first leg of a month's European trip.

Mr. Lillie attended a meeting of the Society of Glass Technology in London, and was in Berne, Switzerland, July 10 for a meeting of the International Commission on Glass. Glass scientists from all over the world were at Berne for this meeting, at which Mr. Lillie represented The American Ceramic Society and the American glass industry.

While in England Mr. Lillie visited several glass plants, and after the meeting at Berne he plans to inspect plants in France, where he will be the guest of Ivan Peyches, Research Director for the St. Gobain Co. Dr. Peyches was in this country in April to receive the Ross Coffin Purdy Award at the 52nd Annual Meeting of The American Ceramic Society. Mr. Lillie will return to this country July 24.

Mr. Lillie has been with Corning Glass Works since 1927, where he has done research on the physical properties of many of the new types of glass the company has developed. He was chairman of The American Ceramic Society's Glass Division in 1948-1949, and will take office as President of The Society at the 53rd Annual Meeting in April, 1951.

• The Sixth National Chemical Exposition has been announced for September 5 to 9 at the Chicago Coliseum.

N. Y. STATE COLLEGE OF CERAMICS CELEBRATES 50TH ANNIVERSARY

The 50th anniversary of the New York State College of Ceramics was celebrated by a special convocation of Alfred University on Sunday, June 11. The principal speaker was Dr. Charles E. Kenneth Mees, Vice-President of Eastman Kodak Company, whose subject was "Education and Technology". Honorary degrees were granted as follows: to C. Forrest Tefft, Claycraft Company, Columbus, Ohio, an alumnus of Alfred and member of the Board of Managers of the College, Doctor of Engineering; Ralph K. Hursh, Professor of Ceramics, University of Illinois, Doctor of Science; Arthur S. Watts, Head of the Department of Ceramics, Ohio State University, 1914-1946, Doctor of Science; Miss Marion L. Fosdick, Professor of Sculpture at Alfred since 1915, Doctor of Fine Arts; and Charles E. K. Mees, Doctor of Science.

Greetings were presented by Dr. George E. Haynes, a trustee of the State University of New York, of which the College of Ceramics is a unit; James W. Hepplewhite, President of the American Ceramic Society; Howard Failmezger, Vice-President of the Ceramic Association of New York; and Paul E. Cox, Alfred 1906, the oldest alumnus of the College.

The Professional Degree of Ceramic Engineer was awarded to Martin G. Babcock, Pittsburgh Plate Glass Company; Leon B. Bassett, New York State College of Ceramics; Robert M. Campbell, New York State College of Ceramics; Leon B. Coffin, Andover China Company; Sandford S. Cole, Titanium Division, National Lead Company; Paul E. Cox, Louisiana Geological Survey; Leon A. Dougherty, Wisconsin Porcelain Company; Kenneth E. Holley, Corning Glass Works; Paul V. Johnson, Structural Clay Products Institute; Douglas W. McConnell, McConnell & McConnell; Clarence W. Merritt, New York State College of Ceramics; Remington M. Murphy, Onondaga Pottery Company; James C. Peck, Glen Gery Shale Brick Company; Gordon D. Phillips, Olean Tile Company; Marvin H. Pond, Ross-Tacony Crucible Company; Thomas M. Place, American Limoges China Company; Leonard F. Sheerar, Oklahoma A & M College; Mark Sheppard, Fairmont Machinery Company; Willard J. Sutton, New York State College of Ceramics; Thomas D. Tefft, McLain Fire Brick Company.

Dr. M. Ellis Drake, President of Alfred University and of the College of Ceramics, presided. Dr. John Nelson Norwood, President Emeritus, gave a brief historical account of the College. An extended history of the College is contained in a souvenir booklet prepared for distribution on this occasion.

ACHESON COLLOIDS APPOINTS TECHNICAL SERVICE ENGINEER

Announcement has been made by M. W. Reynolds, Vice President of Acheson Colloids Corporation, that Melvin L. Bunting has been appointed a Technical Service Engineer of the company.

Mr. Bunting assumes his new position after service with the production and quality control department of the U. S. Gypsum Company in Detroit. Prior to this, he was associated with the Combined Metals Reduction Company. He is a chemical engineering graduate of the Michigan College of Mining and Technology.

INVENTIONS AND INVENTORS

A Summary of Recently Issued Patents of Interest to the Glass Industry

Feeding and Forming

Apparatus for Delivering Charges to Molds. Fig. 1. Patent No. 2,507,753. (Six sheets of drawings.) Homer J. Blackhurst made this invention. The machine shown is of the chain type where the molds travel continuously and a series of funnels follow each mold while the job is being delivered.

A sprocket chain 14 carries a series of press molds 18, the machine being continuously driven by a motor 10. At one point the molds pass below a forehearth 25 which may have a single or double orifice feeder. Six molds 51 are carried at the end of arms and held yieldingly outward by springs. As each funnel approaches the delivery position, a roll on the end of each arm engages a plate 53 which causes the funnel to travel in a straight line for a short distance directly above the mold. The funnels are also arranged for vertical movement toward and from the molds.

The charges are presses while the molds are traveling with plungers 63. The whole machine is properly timed through gears and provision is made for convenient changing of the molds and various necessary adjustments.

The following references are of record in the file of this patent: United States Patents: 1,331,536, Soubier, Feb. 24, 1920; 1,575,370, Lorenz, Mar. 2, 1926; 1,600,488, Rule, Sept. 21, 1926; 1,852,171, Lobb, Apr. 5, 1932; 1,926,764, Dorman, Sept. 12, 1933; 2,111,296, O'Neill, Mar. 15, 1938; and 2,329,146, Teichmann, Sept. 7, 1943.

Skimmer Block for Feeder Forehearths. Fig. 2. Patent No. 2,508,222. (One sheet of drawings.) M. M. Cannon, Jr., assigned this invention to Hartford-Empire Company. The object of the invention is to prevent wear and damage to the skimmer block when it is adjusted or removed.

The skimmer block 3 fits into the flow channel 1 leaving a space between the side walls of the channel into which are fitted two water cooled pipes 8. When the water is turned on, the skimmer block will be frozen in place without any wear occurring on the block or the side walls. When it is desired to remove or adjust the skimmer, the cooling water is turned off permitting the glass between the parts to melt, thus allowing the skimmer to be moved vertically without damage to the refractory.

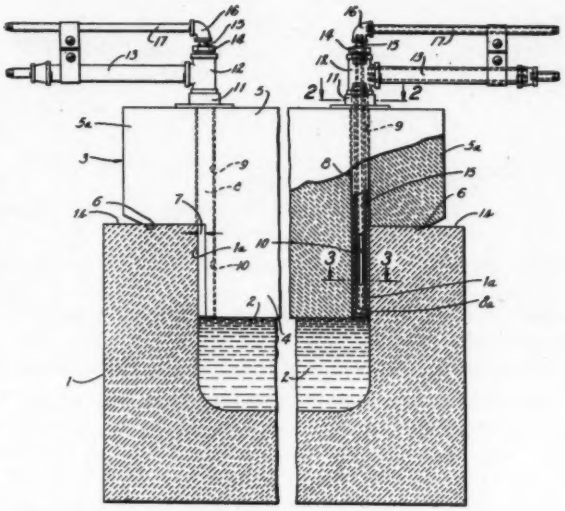


Fig. 2. Skimmer Block for Feeder Forehearths.

The only reference cited in this application was Patent No. 1,641,898 to Neenan, dated Sept. 6, 1927.

Machine for Footing Glassware. Fig. 3. Patent No. 2,508,687. (Eight sheets of drawings.) Harry Richter of Vineland, N. J., assigned this invention to Owens-Illinois Glass Company. This machine is designed particularly for forming a foot or base on containers, such as graduated cylinders.

The machine is of the turret type having six heads which are intermittently advanced to an equal number of working stations. Each head has a chuck comprising jaws 37 which support the cylindrical blank open end down. The chucks are rotated at the proper times by gearing indicated at 70.

The blank is inserted in the chuck at station A and at station B the ends of the blank are heated to the softening point. At station C the upper end of the blank is flared and a pour-out lip is formed on the lower end. At the next station D, a gob of glass is formed into a foot by molds and attached to the blank and at station E this cup-shaped foot is flared into its final form. The finished product is removed at station F.

There are ten references cited by the Patent Office.

Hartford Forming Machine Improvement. Fig. 4. Patent No. 2,508,890. (Six sheets of drawings.) George E. Rowe assigned this invention to Hartford-Empire Company. It is an improvement over what is shown in his earlier Patent No. 2,289,046.

The patent is too long and complicated to make it possible to give an enlightening abstract but the figure selected for reproduction from the 17 of the patent will

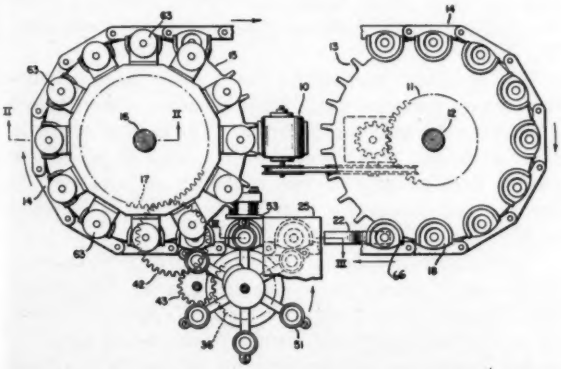


Fig. 1. Apparatus for Delivering Charges to Mold.

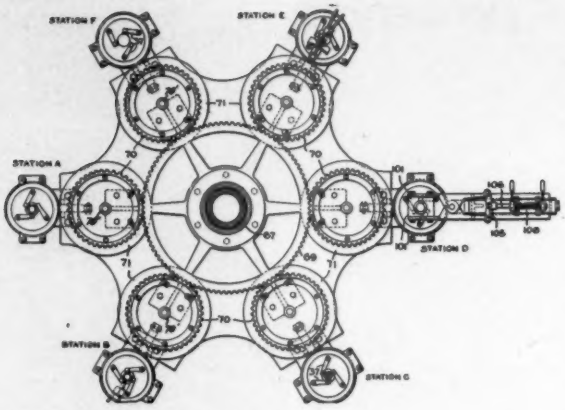


Fig. 3. Machine for Footing Glassware.

enable those familiar with forming machines to recognize the type of invention.

Twenty-two references were cited by the Patent Office.

Hartford Double Gob Forming Machine. Fig. 5. Patent No. 2,508,891. (One sheet of drawings.) This invention was assigned to Hartford-Empire Company by George E. Rowe. It is an improvement over what is shown in his Patent No. 2,289,046 and also over the patent above noted, No. 2,508,890.

As shown in the drawing, this invention has a pair of upwardly moving pressing plungers 28 adapted for use in the Hartford I.S. Machine. The invention is directed to maintaining good operating conditions in the mechanisms associated with each pair of plungers and molds. This includes the movements of the plungers, their cooling and other associated movements.

The plungers are actuated by air cylinders separately controlled by valves 50 and 51 to raise them into pressing position in the molds 37 while a valve 63 retracts the plungers after the pressing operation. Cooling water is supplied by connections to a valve 94. The whole mechanism is fully automatic and various adjustments are provided.

The following references are of record in the file of this patent: United States Patents: 1,039,700, Crawford, Oct. 1, 1912; 1,057,198, Winder, Mar. 25, 1913; 1,466,867, Winder, Sept. 4, 1923; 1,843,160, Ingle, Feb. 2, 1932; 1,911,119, Ingle, May 23, 1933; 1,957,410, Miller, Jr., May 1, 1934; 2,011,980, Miller, Aug. 20, 1935; and 2,289,046, Rowe, July 7, 1943.

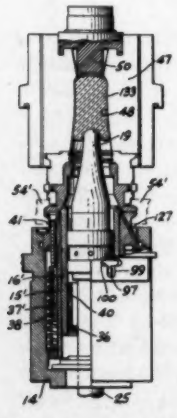


Fig. 4. Hartford Forming Machine Improvement.

Furnaces

Batch Feeder. Fig. 6. Patent No. 2,508,629. (One sheet of drawings.) Ragnar Tanberg of Drammen, Norway, proposes in this patent to feed batch "cemented" by a binder such as evaporated waste sulphite lye from the cellulose industry.

The figure shows the crown 1 of a tank having a jacket 3 projecting upwardly and enclosing a forming tube 4 having a funnel 5 at the top. A

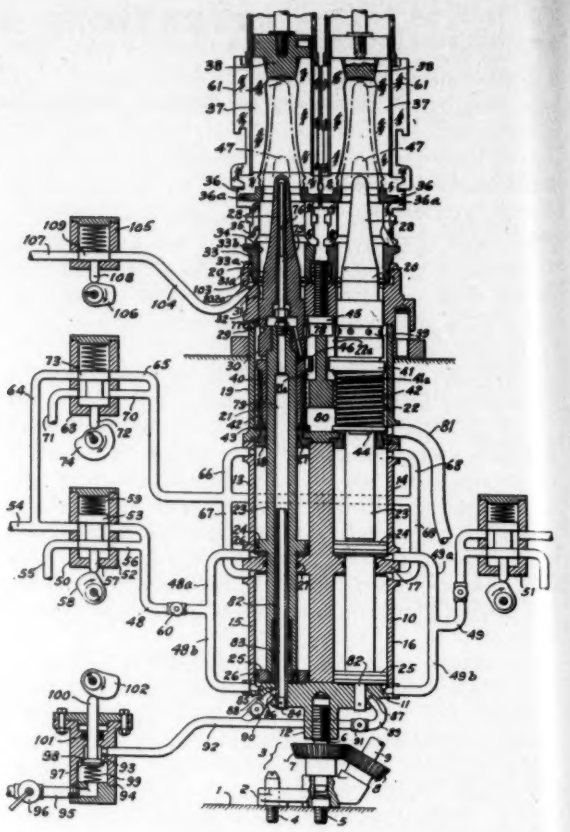


Fig. 5. Hartford Double Gob Forming Machine.

mixture of about 90% batch and 10% of the binder is fed into the funnel. The heat makes this mixture into a compact bar as it passes toward the molten glass 2 where it is melted. A stack 7 provides means for regulating the heat around the tube 4.

The following references are of record in the file of this patent: United States Patents: 708,309, Brown, Sept. 2, 1902; 1,421,211, Good, June 27, 1922; 1,874,799, Peiler, Aug. 30, 1932; and 2,122,241, Arnold, June 28, 1938.

Batch Feeder. Fig. 7. Patent No. 2,509,390. (Three sheets of drawings.) Wilbur F. Gaunder assigned this invention to Pittsburgh Plate Glass Company. The batch feeder of this patent is an improvement over that shown in Patent No. 2,327,887 to Halbach, et al., dated Aug. 24, 1943.

The particular mechanism for pushing the batch into the furnace forms no part of this invention although such a batch feeder is shown in detail. The feature of the invention resides in the provision of a pair of pushers or feeders each adapted to push a blanket of batch into the furnace and means for varying the direction in which each feeder pushes the batch.

The figure is a diagram showing a furnace 10 having a dog house 11 nearly as wide as the furnace. Each feeder has a hopper 50 mounted to turn on rails 41 about a pivot 37 so that the direction of discharge can be adjusted. By setting feeders so that the direction of feed is at a slight angle toward the center line 83, a blanket of batch 82 is

formed and if it is desired to push the blanket toward one or the other of the tank side walls, the angle of one or both feeders may be changed to produce the desired result.

There are eleven references cited by the Patent Office.

Glass Compositions

Hartford Glass Composition. Patent No. 2,508,070. (No drawings.) Aaron K. Lyle assigned this invention to Hartford-Empire Company. The glass of this patent may be colorless or used as a base for making glass of various colors.

The batch for this glass as set forth in Claim 3 is:

A batch for making a soda-lime type glass, comprising sand, alumina, lime, alkali, a sulphate bearing compound, and a fluorine bearing compound mixed in such proportions that the glass made therefrom as determined by analysis of the final glass, will be clear, colorless, and transparent and will have a composition by weight of

	Per cent
SiO_2	73.0 –74.0
Al_2O_3	1.5 – 2.5
CaO	10.3 –12.1
Na_2O	13.0 –14.0
SO_3	0.15– 0.30
Fluorine	0.15– 0.30

No references were cited by the Patent Office.

Optical Glass. Patent No. 2,511,517. (No drawings.) The invention was assigned to Bell & Howell Company by Harold H. Spiegel.

This glass is produced by the fusion of a batch containing a substantial quantity of each of the oxides of boron, silicon, lanthanum, barium, and cadmium and a minor quantity of each of the oxides of beryllium and zirconium, the specific proportions of these ingredients being as follows:

Ingredients	Percentage by weight
B_2O_3	13.5
SiO_2	15
La_2O_3	17
BaO	34.8
CdO	13.3
BeO	4
ZrO_2	2

The batch containing these ingredients is melted and thoroughly mixed by maintaining it at a temperature between 1320° and 1360° C. for thirty-five minutes and then stirring it for thirty minutes while maintaining it at a temperature between 1300° and 1306° C.

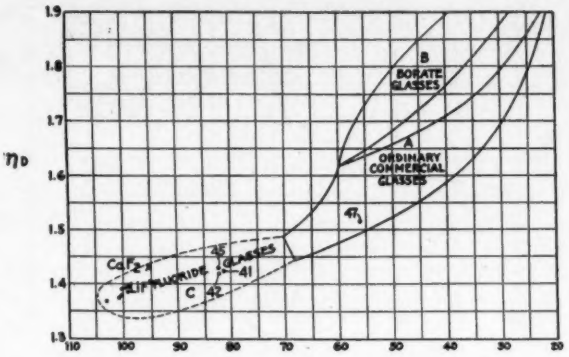


Fig. 8. Fluoride Glass.

The eleven claims of the patent are all directed to the method of making the glass, of which the following is an example: The method of producing an optical glass substantially free from strain and the refractive index of which varies continuously through at least a portion thereof, comprising producing a thoroughly mixed molten batch containing approximately 13.5% of boron oxide, 15% silicon oxide, 17% of lanthanum oxide, 34.8% of barium oxide, 13.3% of cadmium oxide, 4% of beryllium oxide and 2% of zirconium oxide and said oxides being capable of rearrangement from a thoroughly mixed condition to a second condition effecting said varied index of refraction while the batch is in a molten quiescent state, then maintaining the batch in a molten quiescent state for a period of time sufficient to effect said second condition and comprising maintaining the batch at approximately 1300° C. for approximately one hour and then gradually reducing the temperature of the batch to approximately 1090° C. in approximately forty minutes, then reducing the temperature of the batch while it is still in a quiescent state to approximately 600° C. and maintaining it at this temperature for approximately two hours, and finally gradually reducing the temperature of the batch to normal.

The following references are of record in the file of this patent: United States Patents: 1,173,688, Thomson, Feb. 29, 1916; 2,239,551, Dalton et al., Apr. 22, 1941; 2,298,746, Moulton, Oct. 13, 1942; 2,422,472, Dalton, June 17, 1947; and 2,434,148, De Paolis, Jan. 6, 1948. Other References: The Manufacture of Optical Glass and of Optical Systems, Ordnance Dept., Document No. 2037, pub. by Government Printing Office, Washington, D. C., 1921, pages 120, 128, 129, 132, and 134 to 137. (Copy in Scientific Library.)

Fig. 6. Batch Feeder.

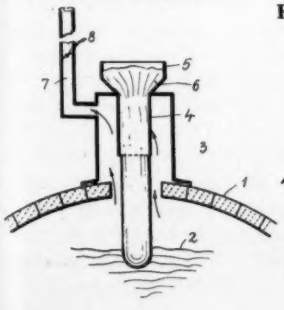
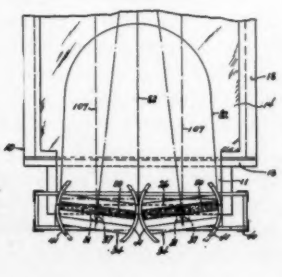


Fig. 7. Batch Feeder.



Eastman Kodak Glass Compositions. Five patents have been granted to Eastman Kodak Company in all of which Kuan-Han Sun appears as sole or joint inventor. These are as follows:

Fluoride Glass. Fig. 8. Patent No. 2,511,224. (Two sheets of drawings.) This invention by Kuan-Han Sun and Maurice L. Huggins relates to a glass having unusual optical properties. The figure is a chart showing the relation between this new glass and those previously known. The patent contains 18 tables in the specification

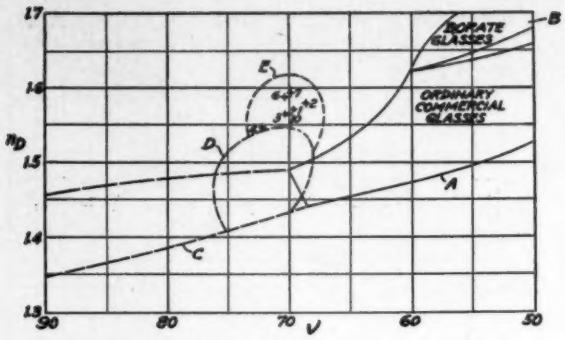


Fig. 9. Fluophosphate Glass.

and five charts in the drawings all of which should be studied in order to get a clear understanding of the invention.

Claim 5 of the patent describes the invention as follows: A moisture-insusceptible, transparent, colorless fluoride glass transmitting ultraviolet radiation down to about 1840 A. and resulting from fusion of a batch consisting of the following fluorides in the percentages by weight given: Magnesium 6 to 13 per cent; calcium 6 to 13 per cent; strontium 5 to 10 per cent; barium 9 to 12 per cent; lanthanum 5 to 16 per cent; thorium 4 to 29 per cent; aluminum 15 to 25 per cent; beryllium 12 to 25 per cent, the sum of the beryllium and aluminum fluorides being between 32 and 50 per cent.

The only reference cited by the Patent Office was Taylor, No. 2,038,691 dated Apr. 28, 1936.

Fluophosphate Glass. Fig. 9. Patent No. 2,511,225. (One sheet of drawings.) Kuan-Han Sun was the sole inventor in this patent. This is an optical glass having high resistance to hydrofluoric acid.

In the figure, the area A includes the values for most commercially available glasses, area B for rare element borate glasses, such as Re-issue Patent No. 21,175 to Morey. Area C for fluoride glasses; D for alkali metal-containing fluophosphate glasses; and E, the area of certain examples of glasses coming under this patent. The numerals in this area indicate the example number as shown in four tables found in the patent.

Claim 6 of the patent is as follows: A fluophosphate optical glass having high resistance to hydrofluoric acid and consisting of the fused heat-reaction product of a batch consisting of aluminum metaphosphate and compatible metal fluorides, the aluminum metaphosphate comprising from 19 to 40 per cent by weight of the batch, and the fluorides including by weight: magnesium fluoride, 0.3 to 0.4 per cent; calcium fluoride, 0.5 to 14.0 per cent; zinc fluoride, 0.3 to 1.0 per cent; strontium fluoride, 0.3 to 0.7 per cent; barium fluoride, 31 to 57.1 per cent; and lanthanum fluoride, 0.5 to 3.0 per cent.

No references were cited by the Patent Office.

Fluophosphate Glass. Fig. 10. Patent No. 2,511,226. (One sheet of drawings.) This composition relates to Patent No. 2,511,225 noted above. It is the invention of Kuan-Han Sun and Thomas E. Callear. It is directed particularly to a glass having a higher partial dispersion in the blue region than the previous glasses of equal Abbé value.

The figure shows the effect of the invention on the index of refraction and the Abbé value when using a batch according to the two following examples:

	Example 1		Example 2	
	Weight Per cent	Mole Per cent	Weight Per cent	Mole Per cent
CdF_2	11.8	15	23.7	30
BaF_2	57.8	63	41.5	45
$Al(PO_3)_3$	30.4	22	34.8	25
N_D	1.5766		1.5959	
V	66.1		62.8	
V_{gF}	.544		.549	

The area H gives the refraction N_D and Abbé value V of these two compositions as compared with ordinary commercial glasses in the area D. Fluoride glasses fall within the area E, fluophosphate glasses according to Patent No. 2,481,700 in area F, and glasses according to the above Patent No. 2,511,225 within area G.

Claim 3 of the patent is as follows: A fluophosphate optical glass consisting of the fused heat reaction product of a batch consisting of metal fluorides and at least one metal phosphate all mutually compatible in glass compositions, said batch containing in mole proportion barium fluoride 35 to 71 per cent, aluminum metaphosphate 14 to 35 per cent, cadmium fluoride 10 to 35 per cent, the total of these three ingredients being 60 to 100 per cent.

The following references are of record in the file of this patent: United States Patents: 2,278,501, Tillyer et al., April 7, 1942; 2,430,539, Kuan-Han Sun, Nov. 11, 1947; and 2,430,540, Kuan-Han Sun et al., Nov. 11, 1947.

(*Continued on page* 389)

Fig. 10. Fluophosphate Glass.

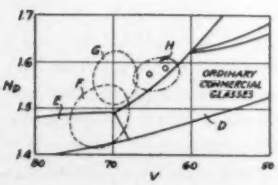


Fig. 11. Lead Containing Fluophosphate Glass.

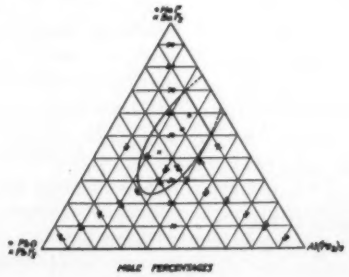
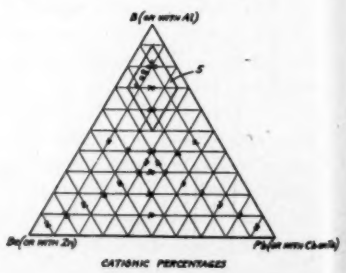


Fig. 12. Lead Borate Glass.



Research Digest

Effect of Humid Conditions on Glass Surfaces Studied by Photographic and Transmission Techniques

The weathering that a glass surface undergoes in service is frequently a factor limiting the uses to which such a glass can be put. The mechanism of the weathering process is not very well understood. Moreover, it has been difficult to establish effective techniques in terms of which the reactions taking place can be more thoroughly studied and in terms of which different glasses can be satisfactorily evaluated.

This work, by G. F. Stockdale and F. V. Tooley (*Journal of the American Ceramic Society*, January 1950), was undertaken to study the course of surface weathering and to evaluate by surface photomicrographs and transmission measurements the effects of different humidity conditions on glasses of widely varying types. A necessary and significant part of this work was that of developing the technique of sample preparation, exposure, and measurement to a point permitting the best reproducibility of results.

The glasses for this work were obtained as ¼-in. thick sheets, rough-ground on both sides. Two were soda-lime glasses, two were borosilicates, and one was a soda-potash-lead glass. One-inch squares were cut from the glass sheets, ground and rouge-polished by a commercial optical company. A final rouge polish was carried out under carefully controlled laboratory conditions.

The test glasses were exposed to atmospheres of 95, 73, and 57% relative humidity at 90°C. by using saturated salt solutions (potassium sulphate, sodium chloride, and sodium nitrate, respectively) to control humidity. To insure uniform exposure conditions, a special design weathering chamber was used, each chamber being completely immersed in a relatively large thermostatically controlled water batch held at the desired temperature. Transmission and reflectance measurements were then made of the weathered samples along with photographs of the weathered surfaces after 24, 28, 360, and 1296 hours of exposure.

Progressive pictures taken of a soda-lime glass sample weathered at 95% relative humidity showed the gradual increase of surface filming with time. Characteristically, the first weathering appears as small local spots, and, as time progresses, these spots coalesce to form larger patches of reaction products. Specimens weathered at lower humidities show a similar pattern of attack but at a greatly reduced rate of reaction. In general, the transmission data for this glass show a gradual loss in transmission with increased time of exposure. These results did not reveal the great differences between specimens weathered at the three humidities that might be anticipated from the microphotographs. Washing the specimens after weathering improved the transmissions.

The other soda-lime glass was of relatively poor durability. After 24 hours of weathering at 95% R.H., the attack had advanced to the stage where the reaction products had coalesced into relatively large patches and, between 24 and 48 hours, the weathering products flowed down the surface, leaving practically clear glass. Between 48 and 1296 hours, the attack continued, but at a much reduced rate. At no time subsequently did the film "slough off". This spontaneous surface cleaning also showed up in the transmission data. Washing these specimens brought the transmissions back very close to their original values.

The lead glass showed a similar pattern of weathering, but the durability as estimated from the photomicrographs was midway between the two soda-lime glasses. It was of interest to note on this glass, as well as on some of the others, the streaks that were accentuated by the weathering process. The streaks are probably the result of polishing, but no evidence of them appeared until after some weathering had taken place.

With the borosilicate glass of the lower durability, after 72 hours of exposure to 95% relative humidity, some evidence of weathering attack appeared on the surface and seemed to be developing in the accustomed manner. Between 120 and 360 hours, however, the patches of reaction product seemed to spread over the surface until at 1296 hours, practically no photographic evidence of attack remained. At the lower humidities, the apparent weathering was so slight that it could not be photographed. This particular glass gained slightly in transmission.

The other borosilicate glass proved to be extremely durable and furnished a check on the reproducibility of the transmission results. Very slight losses in transmission were noted with increasing time of exposure. The losses approached the limit of precision of the measurement and no significant differences between the effects of the three humidities could be detected. After washing, however, the specimens essentially regained their initial transmission characteristics, indicating that the losses had been real and that some weathering had taken place on the surface, even though no microscopic evidence of it could be obtained.

A valuable result of this work is the demonstration that uniform weathering exposures can be obtained if careful procedures are followed and that the methods of measurement have a high degree of reproducibility.

From the standpoint of the mechanism of weathering attack, the results show that for glasses of relatively poor durability, the weathering process proceeds in a similar manner, but at appreciably different rates. The initial weathering customarily begins with many small spots of attack and progresses by the coalescence of these spots to form large patches of reaction products. In some cases, it was further revealed that the patches can become so heavy that a spontaneous surface cleansing occurs.

Weight measurements made periodically throughout the tests on the glass samples indicated negligible losses in weight for all specimens except two which had been weathered at 95% R.H. In the latter cases, after washing, the losses ranged from 1.0 to 1.5 mg. Such low weight losses indicate that only a very small amount of material is removed from the surface during a long period of

exposure to accelerated weathering conditions in spite of the fact that the photographic evidence indicates that it might be appreciable.

Since a small percentage difference in the composition of the soda-lime glasses revealed an appreciable difference in the amount of visible surface attack, the photomicrographic technique would be a means of studying the effect of small composition changes on the weathering characteristics of similar glasses.

The photomicrograph technique also allows an approximate relationship between the degree of relative humidity and the amount of visible attack to be drawn. From the results of this particular study, it was concluded that the times necessary to produce comparable weathering at the three humidities, based on 24 hours of exposure at 95% relative humidity, stand in the approximate ratio of 1:15:54.

A few conjectural statements were made to interpret the seemingly anomalous results obtained between the visual inspection and transmission. It is obvious that phenomena not microscopically apparent are in part responsible for transmission changes caused by the weathering of glasses. The generally greater transmission loss noted in the violet region of the spectrum can be attributed to the scattering effect of the particles of reaction product. Rayleigh's law, which states that the light scattered by small particles varies inversely as the fourth power of the wave length, indicates that more violet radiation would be scattered and less transmitted, thus giving the effect of a greater transmission loss in the violet region.

Opposing the scattering effect is the probability that in some cases the surface reaction removes alkali, leaving a glass higher in silica underneath and having a lower refractive index. Such a condition could effectively produce an anti-reflectance coating and is probably the reason why one of the borosilicate glasses showed a transmission gain that proved to be permanent.

Presented at the recent American Ceramic Society Meeting were the two papers, summaries of which follow.

Color Variations in Glasses Containing Iron: Alkali Calcium Silicates: Other Base Glasses

This paper, presented by G. Brewster and N. Kreidl, color variations in glasses containing iron were studied quantitatively. Ultraviolet, visible and infrared absorption and chromaticity were discussed as a function of concentration, oxidation-reduction equilibrium, and composition.

In alkali calcium glasses, iron produces two bands of absorption in the short wave spectrum, and a band in the long wave spectrum. As the result, there appears a broad transmission maximum causing green coloration. The infrared band is associated with Fe^{2+}, the short wave bands with Fe^{3+}. However, both ions are always present and the shifts in color are due to relative changes in the Fe^{3+} to Fe^{2+} equilibrium. Reduction deepens the red and infrared absorption and decreases the short wave absorption promoting darker, bluish colors. Increase in concentration favors Fe^{3+} over Fe^{2+} and the glasses become darker and yellowish.

The decrease of silica in favor of alkali or boron deepens and broadens the short wave bands resulting in very dark, brown colors. This change is associated with the so-called network forming function of Fe^{3+}. Actually, this function is the result of the effect of less tightly held oxygen on the electronic system of Fe^{3+}. When such glasses are reduced the infrared and red absorption increases as in regular soda lime silicate glasses, but the ultraviolet and short wave absorption does not decrease correspondingly. The result is a deep green color.

Lead and, more so, titanium cause extremely dark brown colors. Phosphorus, characterized by its strong tightening effect on oxygen, affects the ultraviolet and short wave bands in the opposite sense as alkali and boron. They become narrow and move to the ultraviolet, the resulting colors being light and pink. Certain reduced glasses of this type are nearly colorless with a strong absorption in the infrared and are used in the projection of colored moving pictures.

Unusual glasses of widely different chemical composition such as calcium aluminate and titanium fluo-germaniate glasses resemble the "weak" borate or titanium silicate glasses and are brown.

Certain fluo-borosilicate glasses can be compounded to have extremely flat absorption curves by using iron oxide alone and are useful in the design of neutral filters.

The Increased Acid Resistance of Flint Glasses Containing ZrO_2, TiO_2, Ta_2O_5 or Nb_2O_5

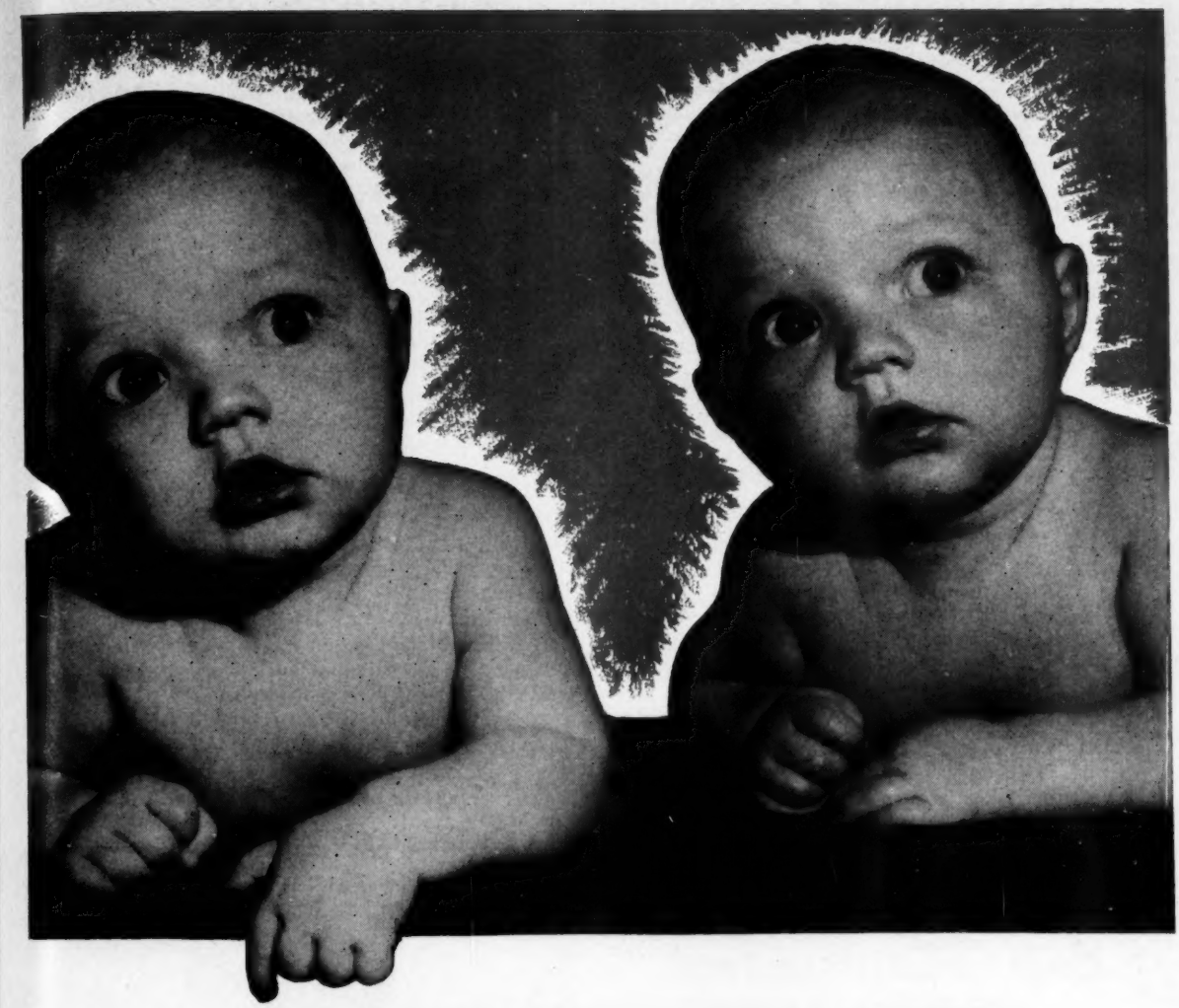
A paper, by M. Aposhian and N. Kreidl, showed that the time required to form a silica rich, low refractive surface layer for film of a specified thickness is used as a measure of the acid resistance of flint glasses improved by the introduction of relatively small percentages of ZrO_2, TiO_2, Ta_2O_5 (or Nb_2O_5). This silica rich film is formed in aqueous acid solutions by a leaching action that removes cations from the glass.

2 mol % TiO_2, ½ Nb_2O_5, ZrO_2, ½ Ta_2O_5 each substituted for lead in a base glass containing 65 mol % SiO_2, 35 mol % PbO, and .02 mols K_2O, improved the filming time from 1.6 hours to 100, 100, 70 and 20 hours respectively in 1% HNO_3 at room temperature. 8% of either TiO_2 or ½ Ta_2O_5 extended the filming time beyond 100 hours in 50% HCl at 90°C. The combination of 1.5 mol % TiO_2 and .5 mol % ZrO_2 resulted in a better durability than any of the sixteen combinations at 2 mol % level in multiple replacements by TiO_2 + ½ Ta_2O_5 + ZrO_2. TiO_2 decreased the index less and increased the softening temperature less than either Ta_2O_5, Nb_2O_5 or ZrO_2. However, the decreases in index caused by Ta_2O_5 are not great and can be compensated, as can those caused by TiO_2, by the omission of a small amount of SiO_2. The introduction of ZrO_2 into these flint glasses is limited by devitrification and insolubility.

I. R. NORTON PROMOTED TO KIMBLE EASTERN POST

Promotion of I. R. Norton to service manager of the New York branch of Owens-Illinois Glass Company's Kimble Division has been announced. He joined Kimble in 1937 and since 1947 has been a member of Kimble's general office in Toledo.

Edward T. Derr, formerly of the Vineland, N. J., plant, has replaced Mr. Norton in Kimble's glass sales and service control division.



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SYLVANIA ELECTRIC EXPANDS RADIO TUBE OUTPUT

Sylvania Electric Products, Inc., has announced an expansion program in connection with its radio tube manufacturing facilities during the next six to nine months to meet an increasingly greater demand.

The first step in the program is the immediate construction of a new plant in Shawnee, Oklahoma, which, when completed around the first of next year, will have a capacity of more than a million radio tubes per month.

C. W. Hosterman, formerly manufacturing superintendent of the Sylvania plant at Huntington, West Virginia, will be Manager of the new plant, which will cover 50,000 square feet and will employ between 400 and 500 persons. Investment in the Shawnee plant will be more than $1,500,000.

MISSISSIPPI GLASS SALES CONFERENCE

Mississippi Glass Company held a sales and manufacturing meeting attended by the entire selling organization, key factory personnel, and administrative officials.

Under the chairmanship of Paul L. Hershfield, President, major subjects covered included quality control and standardization, product development and research, manufacturing procedures, sales, and public relations. Among the highlights of the meeting was a complete tour of the firm's plant, during which the manufacture of its structural corrugated glass and Coolite heat-absorbing and glare reducing glass was observed. Plant improvements and new manufacturing techniques were shown.

NEW LYNCH-UNION CONTRACT

Welfare benefits including hospitalization, medicine, physician's fees and other medical expenses for both the worker and his family are provided in a new contract ratified by employees of the Lynch Corporation.

The 163 Lynch employees are members of the International Association of Machinists. The package proposal approved by the union calls for an hourly wage raise of about 3½ cents and about 8 cents an hour paid into the welfare plan, for each employee, Thomas Myles, business agent of Local 105, reported.

Mr. Myles said the contract is one of the few in this area providing welfare benefits for both the worker and his family.

Also included is an apprenticeship program which will give apprentices four hours' pay at regular rates while they are attending night classes. A clause for the adjustment of wage rates is another feature.

H. WARD ZIMMER ELECTED TO NEW BOARD POST

The Board of Directors of Sylvania Electric Products, Inc. has elected H. Ward Zimmer Executive Vice President of the company, it has been announced by Don G. Mitchell, President.

Mr. Zimmer, who has been Vice President in charge of Operations for the past two-and-a-half years, joined Sylvania in 1919 in the purchasing department at Emporium, Pa. From purchasing he went into manufacturing management, becoming General Manager of the Radio Tube Division in 1942 and Vice President in 1945. He was elected to the Board of Directors of Sylvania last April.

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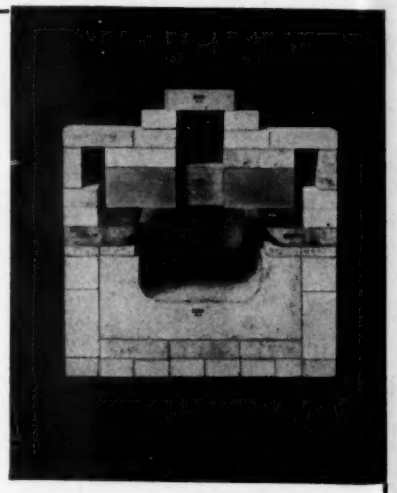

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CURRENT STATISTICAL POSITION OF GLASS

Employment and payrolls: Employment in the glass industry during April 1950 increased to reach a preliminary 112,700. This represents an increase of 3½ per cent over the adjusted figure of 108,800 persons employed during the month of March 1950.

During April 1950, payrolls were also on the increase. Preliminary figures indicate that payrolls for the month were $28,939,625. This is close to 4 per cent above the previous month's adjusted figure of $27,858,965.

Glass container production, based on figures released by the Bureau of Census, for May 1950 was 9,377,251 gross. This represents an increase of 11 per cent above April production which was 8,420,481 gross. During May 1949, production was 7,601,647 gross, or 23 per cent under May this year.

GLASS CONTAINER SHIPMENTS

(All figures in Gross)

	May 1950
Narrow Neck Containers	
Foods	1,274,295
Medicinal & Health Supplies	1,163,334
Chemicals, Household & Industrial	615,518
Beverages, Returnable	818,727
Beverages, Non-returnable	22,214
Beer, Returnable	310,692
Beer, Non-returnable	321,238
Liquors	662,543
Wines	330,719
Toiletries & Cosmetics	523,444
Sub-total (Narrow)	6,042,724
Wide Mouth Containers	
Foods	2,077,350
Dairy Products	271,810
Home Canning	253,328
Medicinal & Health Supplies	287,591
Chemicals, Household & Industrial	114,653
Toiletries & Cosmetics	183,972
Packers' Tumblers	139,424
Sub-total (Wide)	3,328,128
Total Domestic	9,370,852
Export Shipments	272,478
Total Shipments	9,643,330

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in Gross)

		Production May 1950	Stocks May 1950
Foods; Medicinal & Health Supplies; Chemicals, Household & Industrial; Toiletries and Cosmetics	Narrow Neck	3,612,933	3,502,406
	Wide Mouth	2,825,326	2,701,492
Dairy Products		277,886	308,931
Home Canning		*148,650	518,511
Beverages, Returnable		795,590	941,679
Beverages, Non-returnable		22,447	32,724
Beer, Returnable		266,314	429,468
Beer, Non-returnable		309,684	280,666
Liquors		649,509	603,578
Wines		328,841	278,445
Packers' Tumblers		140,071	116,587
Total		9,377,251	9,714,487

*This figure represents Fruit Jars only.

Shipments of glass containers during May jumped to reach the highest single month's shipments since September 1948. 9,643,330 gross of glass containers were shipped during May. This represents a 22 per cent increase over the previous month's 7,879,163 gross. During May 1949, shipments had been 7,861,591 gross, which also represents a difference of 22 per cent. Thus far in 1950, shipments of glass containers have reached 40,324,868 gross, which is well ahead of the 34,634,409 gross shipped during the same period in 1949—a difference of close to 16½ per cent.

Stocks on hand at the close of May 1950 are down about 2 per cent to 9,714,487 gross from the 10,006,167 gross on hand at the close of April 1950. Stocks on hand the end of May 1949 were 9,458,172 gross.

Automatic tumbler production continued upward during the month of May 1950 and reached a total of 6,932,034 dozens. This is close to 6½ per cent above the previous month's 6,515,398 dozens produced. During May 1949, production was 5,242,474 dozens. Shipments of tumblers during May 1950 were 6,410,380 dozens, which represents an increase of about 4 per cent over the 6,167,764 dozens shipped during April. Shipments during May 1949 were 5,054,771 dozens. Stocks on hand at the close of May were 10,460,075 dozens, or 5 per cent more than the 9,937,696 on hand at the close of April. Stocks on hand at the close of May 1949 were 8,614,609 dozens.

Table, kitchen and household glassware: Manufacturers' sales of machine-made table, kitchen and household glassware during May 1950 rose close to 5 per cent to reach 3,421,406 dozens. This increase is over the 3,265,924 dozens sold during April. Sales during May 1949 were 3,672,072. At the close of the 12-month period ending May 1950, manufacturers' sales had reached 39,043,329 dozens. This is about 1½ per cent less than the 39,718,030 dozens sold during the corresponding period ending May 1949.

The figures for automatic tumbler production and sales of table, kitchen and household glassware of two manufacturers are estimated due to these companies' inability to meet The Glass Industry's deadline. However, the totals for these concerns have been estimated in order to complete the compilation of total industry figures. These total figures will be adjusted in the next issue of The Glass Industry.

• Charles A. Scully, formerly with the Sales Department of Chain Store Age for the past six years, has joined McKee Glass Company as Sales Manager of the Chain Store Division. His headquarters will be in New York, N. Y.

CORRECTION: The equation on Page 546 of the October 1949 issue of The Glass Industry should read:

$$q_1 = t \sin i \left(1 - \frac{\cos i}{\sqrt{n_g^2 - \sin^2 i}} \right)$$

James W. Newsome is Chief of the Chemical Development Division, Aluminum Research Laboratories and directs the work of the East St. Louis staff.

NEW ALCOA RESEARCH BUILDING

The completion of a new Alcoa research building at East St. Louis, Illinois, was announced publicly when it was recently opened for the inspection of industrial leaders, educators, and prominent editors. The new laboratory, a three-story building faced with brick, replaced older accommodations at the nearby plant of Aluminum Ore Company (a wholly-owned subsidiary of Aluminum Company of America).

A branch of Alcoa's Aluminum Research Laboratories, the East St. Louis unit develops and improves chemical products derived from bauxite, and investigates methods involved in producing them. Basically, the chemicals manufactured by Aluminum Ore Company are a variety of aluminas and fluorides in different forms and grades.

In designing the new building, utility was emphasized. The laboratory, though plain in decoration and furnishings, is comfortable, convenient, and efficiently arranged. Natural lighting is provided by continuous windows of heat-absorbing glass on each floor level. Comfort air conditioning, with both temperature and humidity control, improves working conditions and helps insure the accuracy of laboratory work during hot, humid summers.

The "Hoods and Furnaces" rooms are separately ventilated and are located so that they can be reached easily by those who need to use them. The three rooms are stacked vertically, one above the other, and are all vented on the roof by a common fan. Separate controls for the fan are located on each floor.

One special furnace room, located in the penthouse, is used for modified Curtis convertors, high temperature ceramic furnaces that develop 3720°F. This room is vented directly through the roof. Another special furnace room on the second floor houses a twenty kilowatt, high frequency induction furnace. In this case, of course, venting is unnecessary for little heat is dissipated in the room by the induction furnace.

The electron microscope housed in the East St. Louis laboratory was the fourth purchased in the United States. Since it magnifies one hundred thousand times, the electron microscope is valuable in observing the particle size and shape of some of the very fine material produced at the East St. Louis plant.

The pilot plant is designed to accommodate materials in carload lots, a sufficient quantity to provide reliable data for plant design. Among the pieces of equipment available for use are a sixty-foot rotary kiln with variable speed and adjustable pitch; a 500-watt, three phase electric furnace; and a variety of driers, filters, and sintering machines.

The local administrative head of the laboratory is G. H. Wagner, an Assistant Director of Alcoa's research laboratories. Mr. Wagner has been with the East St. Louis laboratory since its beginning and has guided the organization to its present position of prominence.

NEW TYPE WINDOW UNIT

The development of an insulating type window unit made of two panes of sheet glass with a pocket of dry air sealed in by a metal-to-glass bond makes it practical to design solar type farm buildings to take advantage of the sun's heat in winter, the American Society of Agricultural Engineers has learned from a paper delivered before the Society by Professor D. C. Sprague of Pennsylvania State College and W. Everett Eakin, Director of farm research for Libbey-Owens-Ford Glass Company.

The double-paned glass with the sealed-in air space, known as Thermopane, will be made available in two thicknesses of glass for farm buildings, double strength window glass for ordinary sized window areas and in the heavy sheet glass for larger windows in buildings such as milking parlors and milk houses or animal shelters where larger openings are desired to take advantage of solar heat.

Development of the insulating windows opens a new frontier in the design of farm buildings, making it possible to reduce the drafts previously caused by windows, avoid much of the condensation and frosting, and making it possible to daylight these buildings more efficiently, according to the paper presented. The insulated windows stay cleaner longer than ordinary small-paned single glazed windows.

WYANDOTTE PURCHASES CALIFORNIA PLANT

Purchase of the Pacific Chemical plant of the American-Marietta Company of Los Angeles, California, by Wyandotte Chemicals Corporation has been announced by Robert B. Semple, President.

Wyandotte Chemicals will immediately revamp the property to provide a Pacific Coast manufacturing unit to serve its branches which have functioned for a number of years in Los Angeles, San Francisco, and Seattle.

Pacific Chemical's plant and sales personnel will be absorbed by Wyandotte's Pacific Division and the Wyandotte research and technical service staffs will become available to users of Pacific Chemical products, as well as users of Wyandotte products.

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(*Continued from page* 358)

safety factor in determining the required time t to reach a stress level F. Accordingly, we can say

$$t = 1/AF \ *$$

for the time to reach level F with an annealing constant A.

In a study of rates at various constant temperatures, it is found that log A is linear with temperature. We can, therefore, say that

$$A = A_a e^{c(T-Ta)}$$

from which, after introducing physical constants for an average glass:

$$t = e^{-.070(T-Ta)}/3.28 \times 10^{-6}F$$

where t is in seconds, T—Ta is the temperature expressed as °C above the annealing point, and F is a stress in p.s.i. suitably within the desired stress tolerance.

It will be noted that thickness does not enter this equation, it being assumed that the whole body has been brought to the temperature T without stress release before time is counted. Such an assumption amounts to another safety factor, particularly in the temperature range where t is small.

Cooling Rate. Assuming a constant rate of cooling and equal thermal transfer at both surfaces, the central plane of a slab will be hotter than the surfaces by an amount:

$$\Delta T = \frac{a^2R}{8k}$$

where a is whole thickness,
R is cooling rate, and
k is thermal diffusivity.

The stress difference between these same two locations in the slab can be expressed

$$\Delta S = \frac{E\alpha'\Delta T}{1-\sigma}$$

where E is Young's modulus,
α' is expansivity in the annealing range and can be called 2α, where
α is the mean 0—300°C linear expansion coefficient, and
σ is Poisson's ratio.

As is generally recognized, the stress distribution is roughly parabolic, so that during cooling ΔS is made up of one part compression in the central plane to two parts tension in the surfaces. As discussed earlier, part or all of this stress will be released during cooling, and that same part will reappear with its sign changed when the temperature gradient is removed. Accordingly, the maximum permanent tension due to the cooling gradient itself will be

$$F = \frac{\Delta S}{3} = \frac{E\alpha a^2R}{12k(1-\sigma)}$$

Certain of the above constants are affected very little by composition, and so can be evaluated:

$E = 7000$ Kg./mm² when F is in Kg./mm²
$= 10^7$ p.s.i. when F is in p.s.i.
$k = .0050$ cm.²/sec. when a is in cm.
$= .00077$ in.²/sec. when a is in inches.
$\sigma = 0.22$, $(1-\sigma) = 0.78$.

* Correct time t will be this value multiplied by $(1\text{-}F/F_o)$ which varies from 1 at $F_o = \alpha$ to 80% when F_o is 5 x F.

So, when we assume the thickness to be in inches and the stress to be in p.s.i., we have

$$F = 1.38 \times 10^9 \alpha\, a^2R, \text{ or}$$
$$R = F/138(\alpha \times 10^7)a^2$$

with R the cooling rate in °C/sec.

The rate R given above applies to that relatively short range of temperatures where the final permanent stresses are being established. In general, for ware of ordinary thickness, this range extends from a few degrees above the annealing point to about 75°C below the annealing point. At lower temperatures the rate is limited only by the ability of the ware to withstand it without breaking. This higher rate is several times R and must be determined from plant experience.

V. Conclusions

Basic annealing principles cannot substitute for good objective plant experience. Even at best, a lehr cannot completely meet the conditions that must be assumed in a basic discussion of annealing. The correction of lehr faults must rest upon a careful study of the stresses existing in the ware.

Further, no amount of basic understanding can make a poor lehr produce really well annealed ware. Spottiness of lehr temperatures and poor temperature control will always be reflected in poorly annealed or variably annealed ware.

It is hoped that the foregoing discussion of annealing will assist the reader in (1) correctly analyzing the reasons for poor results when they occur by comparing these results with those theoretically possible with rates of cooling that are presumed to prevail in the working lehr; and (2) increasing the efficiency of existing equipment by making sure that all cooling rates are as high as is compatible with the tolerances specified for the particular ware in question.

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UNION PRESSES FOR GLASS SALES

A nation-wide campaign to promote the sale of American-made glassware has been started by the American Flint Glass Workers' Union, AFL, according to an announcement by Harry C. Cook, President of the Union.

Mr. Cook said that hundreds of retail merchants throughout the United States have been asked by the glass workers to give the American hand-glass industry all possible cooperation. The merchants were told by Mr. Cook in a letter that critical unemployment exists in the industry because of the competition of imports.

NEW EQUIPMENT AND SUPPLIES

SAVE-A-BLADE DIAL ON CLIPPER MASONRY SAWS

Clipper Mfg. Company, Kansas City 8, Missouri, has announced its Save-A-Blade dial developed to eliminate all guess-work when choosing the correct blade pressure to cut any range of materials, hard or soft. Savings in blade cost are effected by a single setting of the Save-A-Blade Dial to either the Soft-Medium or Hard position.

The new device can be instantly set for glass and marble, brick or tile, concrete products. A quick movement of the dial to the "Diamond" setting and the blade-cutting pressure is automatically set to give fastest cutting with longest blade life. Of the nine different Clipper models of cutting saws, all will be equipped with the new dial, except Model C.

Booklet G.I. 117 describes the new Save-A-Blade Dial and other Clipper exclusive features, including Select-A-Notch, Adjust-A-Cut, and the patented Stabilizer control.

ANALASCOPE

Analytical Measurements, Inc., 585 Main Street, Chatham, New Jersey, has developed a new instrument, the Analascope, which provides a convenient, dependable means for measuring and continuously showing any phenomena that can be translated into electrical impulses.

The instrument can serve as a pH meter which measures to .001 pH, and the next moment it can serve as an electrocardiograph, a pressure indicator, a strain analyzer, or an instrument for measuring any phenomena converted into electrical impulses, whether static, rapidly fluctuating, or of high or low impedance.

Results are displayed on the long persistence screen of a 5″ cathode ray tube. It allows continuous observation of non-recurrent phenomena at sweep speeds of from .01 to 5 seconds. A two decade precision potentiometer calibrated with a self-contained standard cell provides direct measurements from .001 pH to 15 pH and 0.1 millivolts to 1.5 volts.

TWIN SHELL BLENDERS

The Patterson-Kelley Co., Inc., 28 Burson Street, East Stroudsburg, Pa., has announced the addition to its line of twin shell blenders, a transparent laboratory or pilot plant unit for test or small production service.

The shape of the barrel is said to provide a combined tumbling and rolling action, with a simultaneous transverse movement within the entire mass of material. In addition, a folding action results from the alternate combining and dividing of the mass as the blender rotates.

ROTARY TUBULATING MACHINE

Eisler Engineering Co., Inc., 750 South 13th Street, Newark 3, New Jersey, has announced the development of a new machine for high-speed tubulation of vacuum flasks.

A built-in reducer provides continuous rotation to heads through rubber friction drivers, except at load and discharge which is idle. Intermittent motion of turret is provided by Geneva gear. Cast iron turret has skirt construction which seals to the cast iron machine base so as to exclude glass particles. Heads are located on a circle of 26″ diameter (6.729″ chord) and consist of a nest for the exhaust tube as well as 3-point radial nest for one size shell up to 4″ diameter.

The burner system includes manifolds, mixers, and burners for gas-air; piercing burners use gas-air-oxygen. Four stations of the machine are used to preheat glassware; the same number are used to anneal after tubulating. A pair of vertical piercing fires on the end of a long tube are lowered into the glassware by use of a double acting air cylinder and a pair of rams of quill construction. Micro adjustment in two directions locate the piercing fires accurately.

The pneumatic system to operate the air cylinder includes air line filter, pressure regulators, pressure gauge, and automatic oiler. Flow of air is controlled by solenoid-operated air-valve energized from limit switch and cam. Approximately 45 psi are required from 80 psi supply. A 1/3 HP motor complete with adjustable speed pulley is provided.

LABORATORY MIXER

Fisher Scientific Company, 717 Forbes Street, Pittsburgh, Pa., has announced a new type of laboratory mixer designed specifically to break up whirlpool action to produce both horizontal and vertical mixing. It can be used for liquid-liquid, liquid-solid, or liquid-gaseous dispersions.

The Fisher-Goldman mixer employs slightly curved, rotating paddles (adjustable for different viscosities) to effect the actual agitation. Three baffles, freely suspended in the liquid, are added to break up the whirlpool action. The paddle-baffle arrangement mixes the liquid both horizontally and vertically, with the movement proceeding outward, upward, over, down, the liquid being "folded" into itself.

BLAKO GLASS CRANE

Blackman Manufacturing Company has announced the availability of its Blako glass crane through L. H. Butcher Company, Los Nietos, California, sole distributors.

The glass crane mounts on any standard truck chassis and is so designed that it is impossible to accidentally drop a load of glass during its operation, according to the firm's statement. The Blako glass crane consists of a telescoping center post with a carrier track attached to the top; a multiple drum winch and clutch unit; and a power takeoff geared to fit the type truck on which it is mounted.

The center post bolts through the truck bed floor to a base which is attached to the frame of the truck, making a foundation as substantial as the truck itself. The winch is mounted at the front of the bed in the same manner and is connected to the power take-off by means of a chain. The cables, or wire lines, run from the winch drums to the bottom of the post and then vertically to the top where they emerge under the carrier track. One line is attached to the carrier and travels the load on, or off, the bed. The second line runs through the carrier and acts as a drag line, which attaches to and raises and lowers the load. A third line lifts the carrier track to the required height for loading or unloading.

CATALOGUES RECEIVED

Ottawa Silica Company, Ottawa, Illinois, has issued a brochure entitled "50 Years with the Silica Sands of Ottawa" dedicated to the firm's 50th anniversary.

The brochure presents the firm's history since its beginning and traces company officials and the progress of the organization during their terms.

Tempil° Corporation, 132 West 22nd Street, New York 11, New York, is distributing a new brochure describing its line of temperature-indicating products.

Directions for the use and typical applications for Tempilstiks°, Tempilaq°, and Tempil° Pellets are listed. Available temperature ratings cover the range from 113°F. to 2500°F. in closely spaced temperature intervals.

AUTOMATIC GAUGING . . .

(*Continued from page* 365)

ment of glass which is between the rollers of the gauge at the instant break-off occurs at the end of the line will actually be the point at which the break will occur when that piece reaches the end of the line. Thus, this point can be spoken of as the trailing end of the third piece upstream of the break-off point or the leading end of the fourth piece, even though they are not visibly marked as pieces until they contact the cut-off saw farther down the line.

At the instant a piece is broken off, the leading end of another piece, the fourth upstream, just reaches the rollers of the measuring gauge. At this same instant Cam No. I operates to close its two electrical contacts designated as 1 and 2 on the diagram. Closing contact 2 connects the coil of relay A to the contacts of the Indicator-Translator. Closing contact 1 connects the coil of relay A across the line through relay contact A_1. This contact A_1 is, however, open at this instant so that no circuit is established. As the piece of tubing proceeds through the measuring element, Cam I rotates as shown, all the while holding the two contacts closed. If, at any time, either the high or the low tolerance is exceeded, a circuit will be established by the Indicator-Translator to relay coil A which will thereby become energized and close contacts A_1 and A_2. Closing A_1 establishes a circuit to the relay coil independent of the Servo-Gauge and Indicator-Translator and of cam operated contact 2. The relay will, therefore, remain energized thereafter, regardless of the diameter of the piece being measured. This "locking-in" of the relay is the impulse which is "stored" in the system.

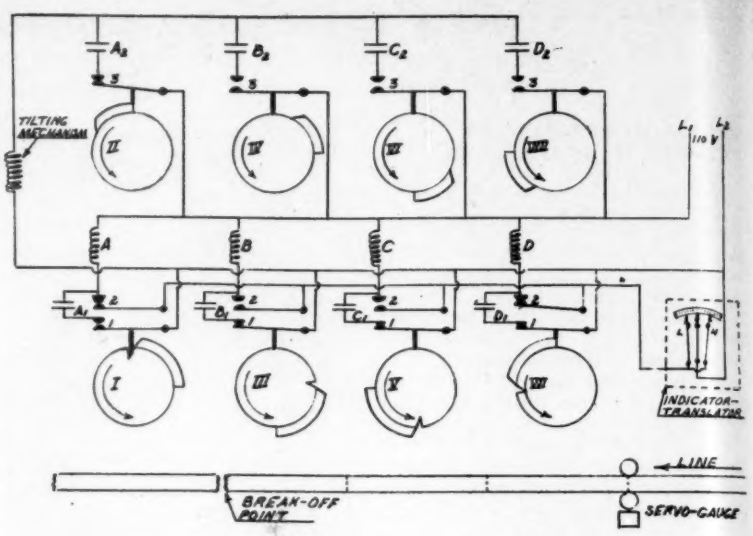

FIGURE 6—DIAGRAMMATIC CIRCUIT OF MEMORY SYSTEM

Just as the trailing end of the piece in question passes through the measuring gauge, Cam I operates to open cam operated switch 2, switch 1 remaining closed. This disconnects relay A from the Indicator-Translator circuit but it remains energized through cam switch 1 and relay contact A_1. At the same instant, the leading end of a new piece enters the measuring gauge and, simultaneously, Cam III operates to close its contacts 1 and 2. This connects relay B to the circuit of the Indicator-Translator. Relays C and D are likewise successively connected to the Indicator-Translator circuit through the action of Cams V and VII as successive pieces reach the gauge unit.

Meanwhile relay A remains "locked-in" which maintains relay contact A_2 in the closed position. As the first piece (that which had the defective spot which caused the relay to be "locked-in") moves out past the break-off point to the sorting table, Cam II operates to close its contact 3 sometime before break-off occurs. This action completes a circuit through relay contact A_2 to the tilting mechanism of the sorting table which causes the defective piece to be deflected to the reject side as it breaks off. Just as the piece is broken off, Cam I operates to momentarily open its contact 1 which deenergizes relay A, thereby releasing the "Impulse" which was "stored" there. This, in turn, deenergizes the tilting mechanism which then returns to its normal position until another piece is to be rejected. Immediately thereafter, Cam I closes both its contacts and the cycle is ready to be repeated just as the leading end of a new piece starts passing through the rollers of the gauge.

Stated briefly, the odd numbered cams, such as I, connect the "storage element" (the relay) to the measuring system when a given piece is passing through the measuring element. The even numbered cams connect the storage element to the sorting device when that same piece reaches the sorting table. Each of the four sections handles every fourth piece.

If, in the above example, the entire length of the piece had been within the tolerances, relay A would not have become energized and relay contact A_2 would have been open when Cam II closed its contact. In this case the tilting mechanism would not have been energized when the piece was broken off and the piece would not have been rejected.

The economies which can be realized from an installation of a system such as this will depend, of course, upon the conditions existing in the particular plant. Experience indicates that in any existing plant continuous automatic gauging and selection will effect an appreciable reduction in production costs and at the same time produce a more uniform product.

PRODUCTION OF WINDOW GLASS IN U.S.S.R.

According to *Steklo i Keramika* (Glass and Ceramics) Jan. 1950, p. 1, the 1949 plan for window glass was fulfilled before time, namely on December 26. No absolute values of production are given.

Daily yield of 1 sq. meter of glass tank was 500 kg. in 1940, 530 kg. in 1948, and 685 kg. in 1949. The rate of drawing glass in Fourcault machines was 51.4 meter/hour in 1940 and 64.6 meter/hour in 1949.

In 1950, among other improvements, drawing of glass from the free surface of melt is to be achieved.

BOOK REVIEWS

Chemical Engineers' Handbook
John H. Perry, Editor

The third edition of the Chemical Engineers' Handbook has been fully revised and expanded to present the most authoritative, up-to-date information on the theory and practice of chemical engineering. Facts, figures, methods and data covering not only chemical engineering itself, but also the related fields, are contained in the Handbook. The volume's comprehensive formulas, equations, charts, tables, schematic diagrams, etc., cover a broad range of topics from flow of fluids, gas absorption and mechanical separations, to process control, furnaces and kilns and plant location.

The Handbook is broken down into thirty sections which have either been completely rewritten or fully revised to keep pace with modern developments and advances.

Published by McGraw-Hill Book Company, Inc., New York, N. Y., 1884 pages, $15.00.

Get Acquainted With Glass
By C. J. Phillips

Dr. Phillips, author of *Glass, The Miracle Maker,* has written a new book on glass which tells how to use glass, what can be done with it, what it is, and how it's made.

Unlike the author's earlier book, his latest is designed for the layman, the homemaker, decorator, student or teacher. The manufacturer, development engineer or designer interested in adapting glass as a better material than that which he has been using, as well as all others requiring a knowledge of glass, will find this book of value.

The book is heavily illustrated and includes a directory of glass manufacturers and a glossary of glass terms. The book opens with a brief history of glass and then goes on to discuss glass in industry, in the home and in science and research. The principles of glassmaking are set forth and are followed with a discussion of facts and figures relating to the industry.

Published by Pitman Publishing Company, New York, N. Y., 235 pages, $4.50.

LACLEDE-CHRISTY ANNOUNCES NEW DIVISION

Donald N. Watkins, President of Laclede-Christy Company, has announced a complete new Division of the company which will be known as the Laclede Arch Company. The company will have engineering and sales headquarters in the Mallers Building, 5 South Wabash Avenue, Chicago 3, Illinois, and will handle industrial furnace enclosures.

Walter W. Shipley, for many years Vice President of the Laclede-Christy Company, will be President of the new Division. Paul J. Maddox will be Vice President in charge of Industrial Sales.

• John M. Neff, Supervisor of Ceramics at Armour Research Foundation of Illinois Institute of Technology, has been named assistant chairman of ceramics and minerals department at the Foundation.

LARGEST GLASS TELEVISION MIRRORS PRODUCED BY AMERICAN OPTICAL

The largest glass television mirrors ever mass produced are now being made, it has been announced by American Optical Company. Manufactured by the company for the Radio Corporation of America, the 26-inch, 90-pound spherical mirrors are intended for use in projection-type theater television and will provide pictures 15 by 20 feet in area.

The mirrors are used in a reflecting-type of optical projection system which allows a small, bright picture on the face of a special cathode ray television tube to be greatly magnified and projected to fill a large screen.

Rigid tolerances are met in producing the giant mirrors. Each one passes a "circle of confusion" test in which light from a small point source is directed at the mirror's surface. When reflected back, all the light rays must fall in a clearly definable circle less than 50 microns (two-thousandths of an inch) in diameter. Following lengthy grinding and polishing operations, the mirrors receive a special aluminized coating deposited in a high vacuum device.

WHEELCO EXPANSION

Chas. L. Saunders, Executive Vice President of Wheelco Instruments Company, has announced the acquisition of the 50 by 120 feet lot adjoining the Wheelco Building.

The new property will be used for a warehouse which will be connected with the plant through a loading platform.

• A gift of $50,000 to the new St. Charles Hospital has been voted by the directors of Libbey-Owens-Ford Glass Company, according to Herbert VonEwegen, General Campaign Chairman.

GLASSES AND GLAZES . . .

(*Continued from page* 369)

inorganic chemical analysis knows that metaphosphates are excellent glass-formers. Chemical analysis and physical properties of a number of glasses based on aluminium phosphate are described by Kreidl and Weyl.

In a most excellent, comprehensive review dealing with colored glasses, Woldemar A. Weyl[10] discusses atomic arrangements in glass and in particular the role played by a series of ions which may modify glass structure. Alumina (Al_2O_3) cannot by itself form a glass because the radius of the cation is too large. But in the presence of an $(SiO_4)^{-4}$ or $(PO_4)^{-3}$ network, it does occur in fourfold co-ordination in glasses, as well as in crystalline silicates, as described above. This is the structural explanation of the special position given to alumina, along with boric oxide, in the glaze formula.

Small amounts of BeO and ZnO may act equally in glass as tetrahedral network. Forming cations TiO_2, on the other hand, will either very much weaken the glass or promote devitrification, as its charge is too high to make it a satisfactory network—modifying cation.

In the introduction to this paper, the statement was made that glass at room temperature is a solid that should have crystallized at some higher temperature but failed to do so. The atomic arrangements in solid glass are now fairly well known and have been described. There is, however, at present, no similar body of established knowledge for the dynamics of glass formation, and this can only be described in general terms. It may be assumed that the tetrahedra and triangles which form the network in the solid already exist to some extent in the melt. Since every oxygen is only linked, in maximum, to two network-forming cations, there is considerable freedom for rotation around every cation-oxygen bond. With falling temperature the tetrahedra may form branched chains or bits of network and the glassy arrangement is so stable or, in other words, the type of bonding so strong that the whole system may be said to get stuck before it reaches the energetically ideal, crystalline state. The principle responsible for glass formation may be described as "maximum entanglement". Energy difference between glass and crystal is so small and the strong bonds within the glassy state so numerous that the rearrangement from glass to crystal does not take place.

It is to be expected that this rather crude picture of the dynamics of glass formation will be amplified by further experimental research which will lead to new progress for glasses and glazes.

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CHARLES D. HAVEN, THERMOPANE INVENTOR, DIES

The death of Charles D. Haven, inventor of Thermopane, the insulating window unit produced by Libbey-Owens-Ford Glass Company, took place at his home at Clear Lake, Indiana, on May 30.

Mr. Haven got the idea for Thermopane while riding on a street car one wintry day in 1930. He couldn't see out of the car and when he got off, he couldn't see into any of the shop windows. He then conceived the double-glazing unit. Originally, he separated two panes of glass with a rubber gasket around the perimeter. The idea was found to have merit and Libbey-Owens-Ford acquired the patents and processes. Then started a long research program which finally resulted in a metal-to-glass bond to replace the rubber or other kinds of organic seals. Mr. Haven remained with L-O-F as a consulting engineer, retiring in 1945. He was 69 years of age. He was credited with several mechanical inventions during his career as a private inventor in Milwaukee.

Mr. Haven had been in ill health since 1947. He leaves his wife, Elfreda; two sons, Charles, Jr., Milwaukee, and Donald, Neenah, Wisc.

RALPH K. HURSH RECEIVES HONORARY DEGREE

Professor Ralph K. Hursh, Department of Ceramic Engineering, University of Illinois, has been granted an honorary degree of Doctor of Science at Alfred University. At the symposium in conjunction with the Fiftieth Anniversary of the founding of the New York State College of Ceramics at Alfred, Professor Hursh presented a paper entitled "Ceramic Education of Today".

A member of the faculty of University of Illinois since 1911, Professor Hursh has contributed greatly to the prestige of the Department and the University. He is a noted authority in such fields as drying and firing of ceramic products, refractories, and structural clay products. His publications include over thirty-five separate contributions to the technical literature.

LIBERTY GLASS TO MANUFACTURE COCA-COLA BOTTLES

The Liberty Glass Company, Sapulpa, Oklahoma, recently received a franchise to manufacture bottles for the Coca-Cola Company in the Oklahoma-Kansas-Arkansas-Texas area. It was only the fourth such franchise ever granted by the beverage firm. Until recently, Coca-Cola bottles were manufactured only by the Chattanooga Glass Company, Laurens Glass Company, and the Owens-Illinois Glass Company.

Trial samples of the bottles were approved by Coca-Cola officials and Liberty Glass Company delivered its first order four days later to a Sapulpa "Coke" bottling firm. The firm, established in 1918, specialized in milk bottles for seventeen years, moving into the carbonated beverage line in 1935.

OFFICIAL OF TOLEDO SCALE IS PROMOTED

Edward D. Jackson, former head of Toledo Scale Company sales operations in the eastern U. S., has been appointed General Sales Manager of the company and moves to Toledo, Harris McIntosh, President, has announced.

Prior to joining Toledo Scale in 1948, Mr. Jackson had directed national sales for several companies in the major appliance field, Mr. McIntosh said. He is a graduate of Yale University.

Mr. Jackson will have charge of all Toledo Scale sales operations, including the marketing of industrial and retail scales, food machines, and restaurant kitchen machines made by the company in Toledo and Rochester.

CORRECTION: The second paragraph on Page 322 of the June 1950 issue of THE GLASS INDUSTRY should read:

Sulphur Content of the Natural Gas

The sulphur content of manufactured gas of around 7-10 grains per 100 cu. ft. has been found to serve as a lubricant when making flares. See Fig. 2 (2). When blowing miniature bulbs, the molds also require similar lubrication.

• Acheson Colloids Corporation is adding a new building unit for the rapidly expanding Dispersed Pigments Division. The new structure is to be ready for occupancy by August 1, 1950.

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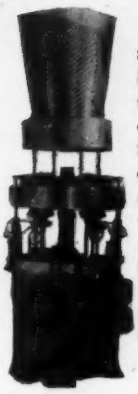

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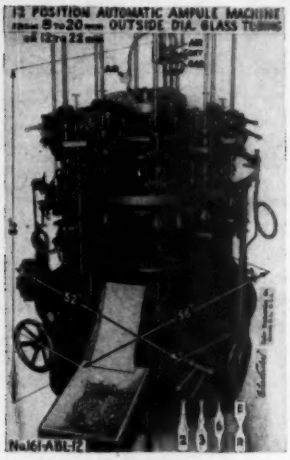

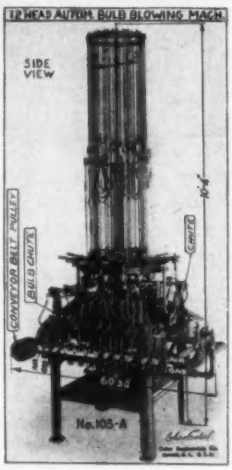

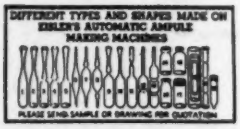
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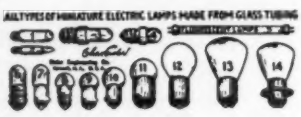

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IMPACT TESTING APPARATUS . . .

(*Continued from page* 359)

The commonly used method of supporting the bottle against the backstop is to provide a V-shaped groove in the backstop and to rest the more or less cylindrical bottle in the groove. Since the bottle is rarely truly cylindrical, it usually contacts the sides of the groove only at two or three points. When it touches at only two points, they are often not at the same height as the place where the blow is delivered and this results in the bottle rocking when hit. By rocking, the bottle sometimes avoids the full force of the blow. At other times it may be struck fairly. The new machine avoids these difficulties by replacing the groove by a V made of two half-round pieces. A bottle held in this V can touch the support at only two points and these points will always be at the same level as the striking head.

The height on the bottle at which the blow is delivered can be set by moving the support on which the base of the bottle is rested. Major changes can be made by releasing the support and moving it to a new height. A hand crank is provided for fine adjustments.

The major part of the machine is made of aluminum alloy and is assembled by welding to give a light and sturdy structure. Those other parts which must be made of steel for weight or hardness are plated to avoid rusting.

A number of glass container companies are now using the machine, and present indications are that it will fulfill the need for a standardized test apparatus for bottles and jars.

COMMERCE DEPARTMENT REPORT ON MIRRORS

"Front surface mirrors" with aluminum reflecting surfaces are recommended for maximum or precise reflectivity in a report now available from the Office of Technical Services of the U. S. Department of Commerce.

The report, a summary of studies of the Army Engineer Research and Development Laboratories, indicates that a silicon monoxide film provides superior protection against abrasion, corrosion, and thermal shock without causing significant loss of mirror reflectivity in the visible or infrared spectrum. Magnesium fluoride protection was found considerably more susceptible to corrosion. Evaporated aluminum was found more suitable as a reflecting surface than silver because of finer grain, smoother surface, and good adherence to the mirror base.

The front surface mirror, which, like conventional mirrors, has a glass base, overcomes the loss of reflecting power and the tendency toward dual reflections noticed when the reflecting surface is placed behind the glass. In optical equipment, for example, back-surface mirrors have definite draw-backs. In outdoor use, however, the front surface mirror must be protectively coated.

Orders should be addressed to the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Refer to PB 92821, Silicon Monoxide Front Surface Mirrors, 30 pages including photographs, drawings, graphs, and tables. Price 75¢. Money order should be addressed to the Treasurer of the United States.

INVENTIONS AND INVENTORS . . .

(*Continued from page* 374)

Lead Containing Fluophosphate Glass. Fig. 11. Patent No. 2,511,227. Kuan-Han Sun made this invention which relates to a glass such as disclosed in Patent No. 2,481,700 granted to the same inventor.

The only figure in the patent is reproduced here. The points on this diagram represent mole percentages. The glasses enclosed by the curve are those which can be made without devitrification under the scope of this patent. The dotted part of the curve below the 10 per cent line indicates that the effect of lead is not appreciable below 10 per cent.

The following table gives 4 examples of compositions coming under this patent.

	Example 1		Example 2		Example 3		Example 4	
	W	M	W	M	W	M	W	M
NaF	20	59.6	17	54.4	...	..	...	..
BaF_2	..	...	..	...	31.5	40	33.4	42
PbO	29	16.2	35	21.2	...	..	...	..
PbF_2	..	...	..	...	33.0	30	36.7	33
$Al(PO_3)_3$ ..	51	24.2	48	24.4	35.5	30	29.9	25

No references were cited by the Patent Office.

Lead Borate Glass. Fig. 12. Patent No. 2,511,228. Kuan-Han Sun was joint inventor in this patent, the others being Thomas E. Callear and Philip T. Scharf. This composition produces an optical glass particularly useful in the manufacture of compound lenses.

The figure reproduced here from the single sheet of drawings shows, within the area 5 on the triangular diagram, the best glasses coming under this patent. The following table gives examples of some glasses within the scope of the invention. The percentages are given both with respect to weight (W) and to cationic (C) ratios.

Example	$BO_{1.5}$		$AlO_{1.5}$		PbO		$CbO_{2.5}$		$TaO_{2.5}$		BeO		ZnO	
	W	C	W	C	W	C	W	C	W	C	W	C	W	C
A	50	79.7	..	...	46	11.4	..	..	..	..	4	8.9	..	...
B	50	77.1	4	4.2	42	10.1	..	..	..	..	4	8.6	..	...
C	47	71.4	7	7.2	35	8.3	..	..	..	..	4	8.5	7	4.6
D	42	65.5	14	15.4	36	9.0	..	..	..	..	3	6.7	5	3.4
E	48	70.6	8	8.0	27	6.2	5	1.9	..	..	4	8.9	8	5.0
F	47	71.3	7	7.3	25	5.9	..	..	10	2.4	4	8.5	7	4.6
G	41	64.9	10	10.8	35	8.6	..	..	..	..	4	8.8	10	6.8
H	31	52.8	15	17.5	35	9.3	..	..	..	..	4	9.5	15	10.9

Claim 1 of the patent reads: An optical borate glass having an index of refraction between 1.6 and 1.7 and an Abbé value between 40 and 45, consisting of the heat reaction product of a batch of oxides in which there is a cationic percentage of beryllium between 5 per cent and 25 per cent, a cationic percentage of lead between 5 per cent and 25 per cent, a cationic percentage of boron between 50 per cent and 90 per cent not over 10 per cent being silicon and the remaining oxides being compatible in the glass composition.

The following references are of record in the file of this patent: United States Patents: 2,294,373, Batchell, Sept. 1, 1942 and 2,406,580, Bastick et al., Aug. 27, 1946. Foreign Patents: 388,118, Great Britain, 1933.

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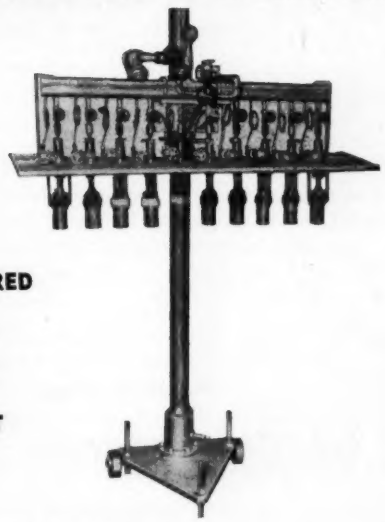
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